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GROUND-WATER CONDITIONS IN THE KAIPAROWITS PLATEAU AREA, UTAH AND ARIZONA, WITH EMPHASIS ON THE NAVAJO SANDSTONE

by

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Prepared by
the United States Geological Survey
in Cooperation with
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Division of Water Rights

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ILLUSTRATIONS

[Plates are in pocket]

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CONVERSION FACTORS

For readers who prefer to use metric units, conversion factors for inch-pound units used in this report are listed below:

Multiply inch-pound units	By	To obtain
acre	0.4047	square hectometer
	0.004047	square kilometer
acre-foot (acre-ft)	0.001233	cubic hectometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot squared per day (ft^2/d)	0.0929	meter squared per day
gallon per minute (gal/min)	0.06308	liter per second
inch (in)	25.40	millimeter
	2.540	centimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Water temperature is given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

$$°F = 1.8(°C) + 32$$

DEFINITION OF TERMS

Chemical Classification of Ground Water

Water quality in terms of concentrations of dissolved solids has been classified as follows:

Classification	Concentration, in milligrams per liter
Fresh	Less than 1,000
Slightly saline	1,000-3,000
Moderately saline	3,000-10,000
Very saline	10,000-35,000
Briny	More than 35,000

Hydrologic Properties of Water-Bearing Materials

Lohman (1972) and Hood and Danielson (1981) have defined hydrologic properties of water-bearing materials. Porosity (N) is defined by Lohman (1972, p. 3) as the ratio of the volume of interstices to the total volume of a rock or soil, expressed as a fraction or percentage. Hood and Danielson (1981, p. 5) define hydraulic conductivity (K) of a water-bearing material as the volume of water that will move through a unit cross section of the material in unit time under a unit hydraulic gradient.

Transmissivity (T) is defined by Lohman (1972, p. 6) as the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient, and is equal to the average hydraulic conductivity of the aquifer times the thickness of the aquifer. Units are feet squared per day. Lohman (1972, p. 8) defines storage coefficient (S) as the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. The storage coefficient is dimensionless.

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ABSTRACT

The Kaiparowits Plateau area is located in central Garfield and eastern Kane Counties of Utah and north-central Coconino County of Arizona. The area covers about 4,850 square miles and includes the drainages of the Escalante and Paria Rivers, and several smaller drainages to the Colorado River between the Escalante and Paria River drainages.

The consolidated-rock aquifer that has the most potential for ground-water development is the Navajo Sandstone of Triassic(?) and Jurassic age. The Entrada Sandstone of Jurassic age is a secondary aquifer, and the Wingate Sandstone of Triassic age presently is not developed but potentially is a significant aquifer. The top of the Navajo Sandstone ranges in depth from the surface near Boulder, on the Paria Plateau, west of the East Kaibab monocline, and in the canyons of the Escalante and Paria Rivers, to as deep as 4,500 feet below land surface in the center of the Kaiparowits Plateau. The aquifer is confined naturally under the Kaiparowits Plateau and near where U.S. Highway 89 crosses the Paria River, and artificially along the shores of Lake Powell.

Annual recharge to and discharge from the Navajo Sandstone is estimated to be between 8,300 and 16,900 acre-feet. The majority of recharge occurs by infiltration of precipitation into the Navajo Sandstone outcrop, especially from snowpack at higher altitudes on Boulder Mountain, and where the Navajo is extensively fractured, for example, west of the East Kaibab monocline. The amount of recoverable water in storage in the Navajo Sandstone is estimated to be about 190 million acre-feet.

In areas where water table conditions exist in the Navajo Sandstone, water is generally fresh (contains less than 1,000 milligrams per liter of dissolved solids). In areas where water in the Navajo is confined, water is generally slightly saline (contains 1,000-3,000 milligrams per liter of dissolved solids). Dominant ions in areas of water-table conditions are calcium, magnesium, and bicarbonate. In areas of confined conditions, sodium and sulfate are the dominant cation and anion in the water.

Inundation of Glen Canyon and tributary canyons by Lake Powell has caused a large increase in the altitude of the potentiometric surface near the lake, as much as 357 feet at well (A-41-8)4dda-1, about 2.2 miles from the lake. Some increase in the altitude of the potentiometric surface has occurred as far as 11 miles from the shoreline of the lake.

Inundation has caused changes in the chemistry of ground water near Lake Powell, primarily where the ground-water level has increased to an altitude higher than that of the Navajo Sandstone-Carmel Formation contact. Major ion chemistry has been altered, the most notable change being an increase in sulfate concentration and a decrease in bicarbonate plus carbonate concentration. Analyses of water from three water-supply wells in the Glen

Canyon National Recreation Area have shown arsenic concentrations in excess of the maximum recommended for drinking water.

The Kaiparowits Plateau area contains large quantities of energy resources. Because of the small amount of recharge to and natural discharge from the Navajo Sandstone in the study area, large withdrawals, such as those required for continued exploration for and development of those energy resources, primarily would be from storage rather than from diverted discharge.

INTRODUCTION

Purpose and Scope of the Study

This report presents results of investigation of ground-water conditions in the Kaiparowits Plateau area of south-central Utah and north-central Arizona (fig. 1). The area is under investigation for development of its large quantities of energy resources, primarily coal. Production and transportation of those energy resources would require attendant development of water resources. The purpose of this study was to determine the availability and quality of ground water in major aquifers in the area--namely aquifers in the Entrada, Navajo, and Wingate Sandstones; emphasis was on the Navajo Sandstone. The study was made by the U.S. Geological Survey in cooperation with the Utah Department of Natural Resources, Division of Water Rights. Field work was done intermittently during July through October 1979, and October 1980 through October 1981.

Previous Investigations

Several workers have made reconnaissance appraisals of ground water in the Kaiparowits Plateau area prior to this study. Gregory and Moore (1931) reported on a geographic and geological reconnaissance of the Kaiparowits area in which they briefly described ground water in the area. Goode made two hydrologic reconnaissances (1964, 1966) in western Kane County, Utah, which included parts of the Wahweap Creek and Paria River drainages, and one reconnaissance (1969) in the upper Escalante River drainage. Cooley (1965) made a detailed spring inventory in Glen Canyon and tributary canyons, most of which are now occupied by Lake Powell. Feltis (1966) compiled information about wells and springs in the Colorado Plateau, including most of the Kaiparowits Plateau area. Price (1977a, 1977b) compiled two maps dealing with the ground-water availability and quality in the Kaiparowits coal-basin area. The Kaiparowits coal basin includes much of the Kaiparowits Plateau area described in this report. Levings and Farrar (1978) investigated ground-water conditions in the House Rock area of Arizona, which includes all of Arizona under consideration in this study. The information collected by Levings and Farrar has been used extensively for the Arizona part of this report.

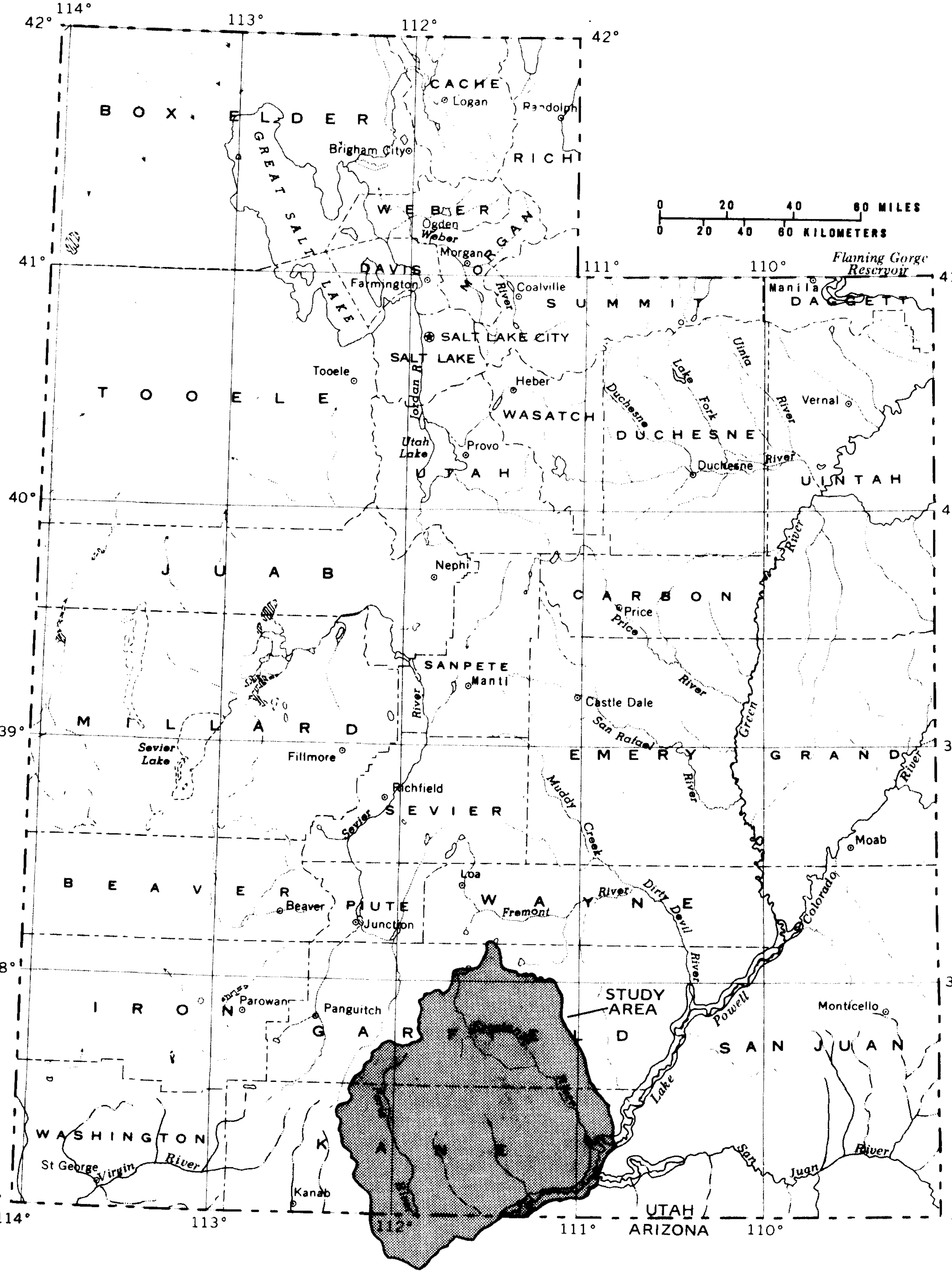

Figure 1.—Location of the Kaiparowits Plateau area.

General Description of the Study Area

The Kaiparowits Plateau area is in central Garfield and eastern Kane Counties, Utah, and north-central Coconino County, Arizona. The area includes the drainages of the Escalante and Paria Rivers, and of several smaller tributaries to the Colorado River located between the Escalante and Paria Rivers: Wahweap (the largest), Warm, Padre, Last Chance, and Rock Creeks (pl. 1). The entire study area covers about 4,850 square miles.

The Kaiparowits Plateau area is part of the Colorado Plateaus physiographic province (Fenneman, 1931, p. 274-325). The province generally consists of nearly flat-lying sedimentary strata that are deeply incised by major stream systems and interrupted by generally north-south trending monoclines and structural domes. Extrusive and intrusive igneous features are found intermittently throughout the province.

The Kaiparowits Plateau consists of nearly flat-lying sedimentary rocks and overlies much of the Kaiparowits structural basin. It is bounded on the west by the Cockscomb, a hogback formed along the East Kaibab monocline, and on the east by the Straight Cliffs, a cuesta formed along the west limb of the Circle Cliffs upwarp. The area, about 1,670 square miles in extent, all drains to Lake Powell on the Colorado River.

The Paria River basin is west of the Kaiparowits Plateau and includes about 1,410 square miles. Kaibab Gulch and Paria Canyon are significant erosional features that have been incised into the Navajo Sandstone. The maximum depth of Kaibab Gulch is about 700 feet, and that of Paria Canyon is about 1,000 feet. Paria Canyon separates the Kaiparowits Plateau to the northeast from the Paria Plateau to the southwest.

The Escalante River basin lies north and east of the Kaiparowits Plateau and includes about 1,770 square miles. The canyons of the Escalante River and its tributaries are cut primarily in Navajo Sandstone, and the river is incised in places as much as about 1,000 feet. The southern flank of Boulder Mountain, the only igneous feature in the Kaiparowits Plateau area, is in the northernmost part of the Escalante River basin.

Altitudes in the Kaiparowits Plateau area range from 3,116 feet at Lees Ferry, Arizona, to 11,328 feet on Boulder Mountain. The altitude of the Kaiparowits Plateau ranges from about 5,000 feet in the south to about 7,000 feet in the north, and the altitude of the Paria Plateau ranges from about 5,000 feet in the north to about 7,000 feet in the south.

The climate of the study area is dry according to the classification of Trewartha (1968, p. 358-369, 370-381), with annual evapotranspiration exceeding annual precipitation. Trewartha's classification indicates that the study area's lower altitudes are arid or desert and the middle to upper altitudes are semiarid or steppe. The uppermost altitudes have a highland climate. According to Strahler (1970, p. 166-168, 227-244), vegetation types vary from sagebrush-scrub in the lower altitudes to pinyon-juniper forest in the middle altitudes to needle-leaf forest in the uppermost altitudes.

Much of the land in the study area is administered by the Federal Government, primarily by the U.S. Bureau of Land Management (BLM). Included in BLM-administered lands are the Paria Canyon Primitive Area and several areas near the towns of Escalante and Boulder designated as Outstanding Natural Areas. Two areas under jurisdiction of the National Park Service lie partly in the study area: Bryce Canyon National Park in the northwest and Glen Canyon National Recreation Area in the southeast (pl. 1).

Community centers in the area and their 1980 populations are: Boulder (112), Cannonville (135), Escalante (654), Henrieville (167), and Tropic (335). All are located along Utah State Highway 12, which crosses the northern part of the study area. The primary economic activity in Cannonville, Henrieville, and Tropic is agriculture. Boulder is involved chiefly with agriculture and forestry, and primary economic activities in Escalante are agriculture, forestry, and oil exploration.

Numbering System for Hydrogeologic-Data Sites

The system of numbering hydrogeologic-data sites in Utah is based on the cadastral land-survey system of the U.S. Government. The number, in addition to designating a well, spring, or related site, describes its position in the land net. By the land-survey system, the State is divided into four quadrants by the Salt Lake base line and meridian, and these quadrants are designated by the uppercase letters A, B, C, and D, indicating, respectively, the northeast, northwest, southwest, and southeast quadrants (fig. 2). Numbers designating the township and range (in that order) follow the quadrant letter, and all three are enclosed in parentheses. The number after the parentheses indicates the section, and is followed by three letters indicating the quarter section, the quarter-quarter section, and the quarter-quarter-quarter section--generally 10 acres[1]. The letters a, b, c, and d indicate, respectively, the northeast, northwest, southwest, and southeast quarters of each subdivision. The number after the letters is the serial number of the well or spring within the 10-acre tract. The letter S preceding the serial number denotes a spring. For half townships and ranges, the letter "T" or "R", respectively, precedes the parentheses. If a well or spring cannot be located within a 10-acre tract, one or two location letters are used and the serial number is omitted.

Thus (D-33-4)35bbd-1 designates the first well constructed or visited in the SE1/4NW1/4NW1/4 Sec. 35, T. 33 S., R. 4 E., and (C-40-1)23bba-S1 designates the first spring inventoried in the NE1/4NW1/4NW1/4 Sec. 23, T. 40 S., R. 1 W. Hydrogeologic-data sites in Arizona are numbered in the same manner except the numbering system is based on the Gila and Salt River base line and meridian.

The numbering system without serial numbers also is used to show the location of data sites other than wells and springs. Such data sites include locations where geologic cores and outcrop samples were collected.

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[1]Although the basic land unit, the section, is theoretically 1 square mile, many sections are irregular. Such sections are subdivided into 10-acre tracts, generally beginning at the southeast corner, and the surplus or shortage is taken up in the tracts along the north and west sides of the section.

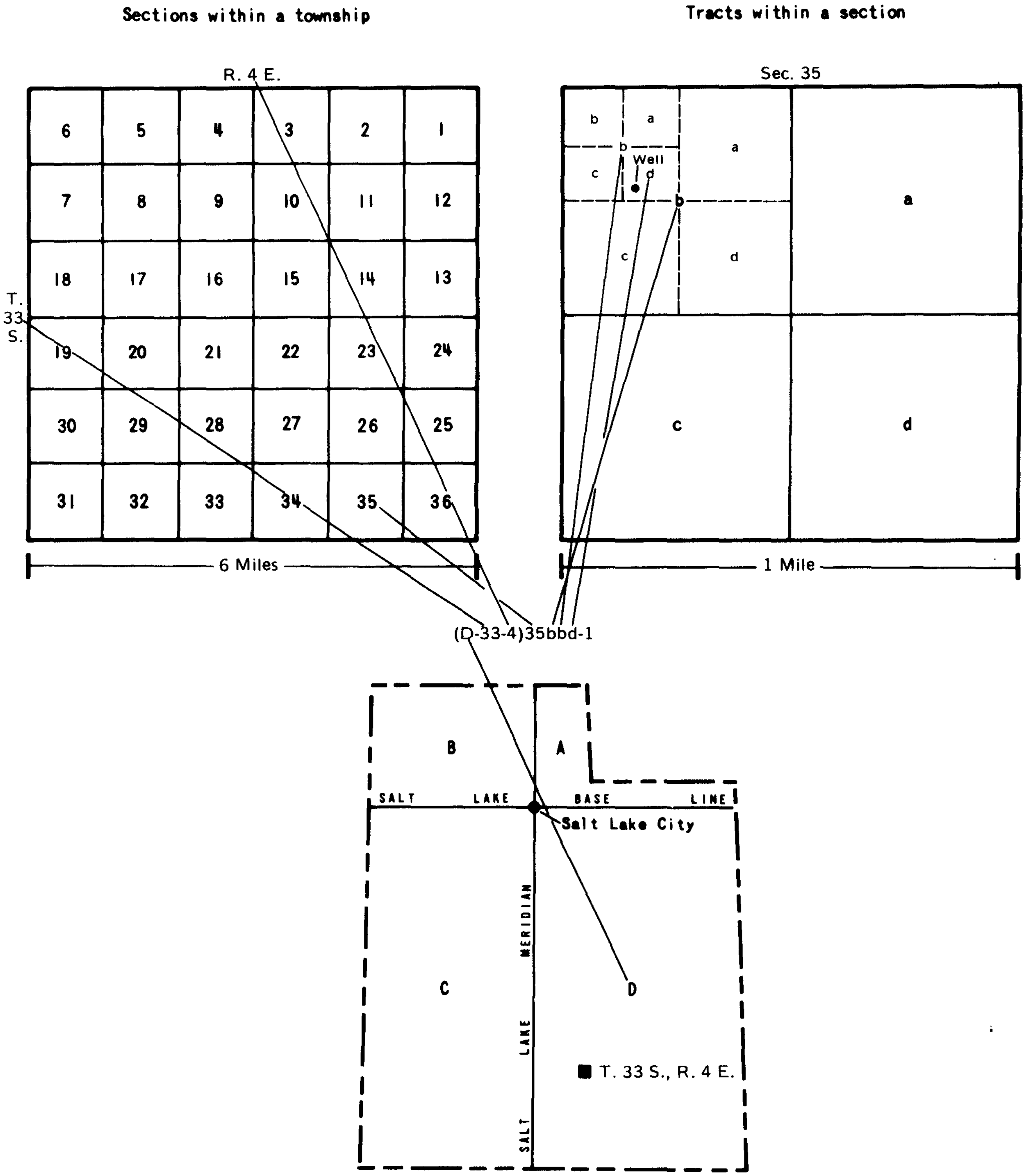

Figure 2.—Numbering system for hydrogeologic-data sites in Utah.

Locally, there is some conflict between locations based on geographic features and those based on the land-survey system, because of the small scale of the maps used. Where such conflicts exist, data sites have been plotted with reference to the local geography, resulting in apparent mislocation with reference to the land-survey system.

Acknowledgments

Several individuals and agencies have assisted in obtaining data for this study. Thanks go to the U.S. Bureau of Reclamation and the National Park Service for access to supply and observation wells in the Glen Canyon National Recreation Area, to the Arizona Department of Transportation for access to supply and observation wells, and to the U.S. Bureau of Land Management at Cedar City for overall assistance. Thanks also are extended to well owners who allowed access to their wells and particularly to Mark and Kim Nelson of Boulder who allowed use of their well for aquifer testing. Thanks also are due to Sam and Vivian Crosby and to Grant and Cathie Johnson for sharing their knowledge of the Boulder area.

GEOLOGY AND ITS EFFECTS ON HYDROLOGY

Stratigraphy

The age of consolidated rocks exposed in the study area ranges from Permian to Tertiary. Those rock units are shown on plate 2 and described in table 1.

From oldest to youngest, the formations under consideration in this report are: the Wingate Sandstone of Triassic age, the Kayenta Formation of Triassic(?) age, the Navajo Sandstone of Triassic(?) and Jurassic age, and the Page Sandstone, Carmel Formation, and Entrada Sandstone of Jurassic age. Of these, the Wingate Sandstone, the Navajo and Page Sandstones combined, and the Entrada Sandstone are the three principal aquifers in the area. Drillers' logs of selected wells (table 11, at back of report) give descriptions, thicknesses, and depths to the surface of the formations at selected well sites.

The Lukachukai Member is the only member of the Wingate Sandstone present in the study area. It generally is a pale reddish-brown, light-brown, or grayish-orange, very fine to fine-grained, crossbedded, aeolian quartzose sandstone. Crossbedding is large scale and high angle. The sandstone erodes to form prominent vertical cliffs that commonly are coated with dusky-red desert varnish. The Wingate Sandstone presently is unused but potentially is a significant aquifer.

The Kayenta Formation is a reddish-brown, reddish-orange, pale-gray, greenish-gray, and lavender fluvial sandstone, siltstone, and shale, with minor shale pellet conglomerate and freshwater limestone. Generally the Kayenta retards water movement between the Wingate and the Navajo Sandstones; however, Cordova (1978, p. 23) and Hood and Danielson (1979, p. 34) indicate that there are instances of leakage through the Kayenta, either where sandy facies are predominant or where the formation is fractured. There is evidence of leakage through the Kayenta in the Kaiparowits Plateau area as well, specifically under the Paria Plateau.

Table 1.--Description of geologic formations in the Kaiparowits Plateau area
[Geologic characteristics adapted from Hackman and Wyant (1973), Stokes (1964), Haynes and Hackman (1978), and Peterson and Pipiringos (1979).]

Erathem	System	Series	Geologic unit	Principal locations of outcrop	Geologic characteristics	Hydrologic characteristics
Cenozoic	Quaternary		Undifferentiated alluvium	Chiefly on southern flank of Boulder Mountain, small areas along southern margin of Vermillion Cliffs and southwestern margin of the Kaiparowits Plateau.	Sand, silt, and gravel.	Unknown.
			Relatively younger alluvium	Chiefly in upper reaches of the Paria and Escalante Rivers and their tributaries, significant area in Alvey Wash.	Do.	Yields water to wells in and near Boulder, Cannonville, Escalante, and Henrieville for domestic use, stock watering, and irrigation.
			Gravel surfaces	Small areas in North Creek drainage.	Mainly terraces and pediments undergoing erosion. May or may not be associated with active streams.	Unknown
			Landslide and other gravity deposits	Chiefly on southeastern flank of Boulder Mountain.	Surficial masses moved chiefly by gravity.	Do.
			Dunes--chiefly quartz sand	Chiefly along the northern margin of the Paria Plateau.	Chiefly quartz sand. Includes both active and inactive accumulations.	Do.
			Covering deposits	Chiefly along the eastern margin of the Kaiparowits Plateau.	Chiefly windblown silts lacking dune form. Some patches of alluvium and soil are included.	Do.
	Tertiary		Undifferentiated Tertiary volcanics Late Tertiary andesite- trachyte-latite flows Late Tertiary basalt and andesite flows	Chiefly in the northern part of the study area--Boulder Mountain.	Extrusive igneous material.	Unknown, but most likely a good recharge medium.
		Eocene	Wasatch Formation	Northwestern part of study area--Pink Cliffs, Table Cliffs, and Canaan Peak.	Mostly light-gray to pink, thick-bedded, fine-grained, fluvial or lacustrine clastic silty limestone, containing thin interbeds of red or gray mudstone and light-gray calcareous sandstone; conglomeratic and less limy in upper 300 feet. Weathers and erodes to badlands, notched cliffs, and ledgy talus-littered slopes. As much as 1,700 feet thick.	Yields fresh water to springs in amounts as much as 450 gallons per minute.
Mesozoic	Cretaceous	Upper	Kaiparowits Formation	Extensive outcrop east of the East Kaibab monocline and northeast of Henrieville.	Predominantly grayish-green to olive, friable, lenticular, arkosic and biotitic silty sandstone; sparse thin interbeds of light-gray mudstone, lenticular pelletal gray limestone, and brown resistant sandstone; sparsely fossiliferous; continental; erodes to gentle slopes. 2,000 to 3,000 feet thick.	Provides base flow to streams and yields small amounts of water to springs, generally less than 40 gallons per minute. Water is generally fresh to slightly saline.
			Wahweap Sandstone	Extensive outcrop in the center of the Kaiparowits Plateau, flanking the outcrop of the Kaiparowits Formation on the west, south, and east.	Alternating thin to thick fluvial beds of yellowish-gray mudstone and pale-yellowish-gray to buff well-cemented sandstone; mudstone more abundant near base; persistent thick conglomeratic sandstone in upper 300 feet; erodes to ledgy cliffs and slopes. As much as 1,500 feet thick.	Yields small amounts of water to springs, generally less than 5 gallons per minute. Water is generally fresh to slightly saline.
			Straight Cliffs Formation	Extensive outcrop in the southern and eastern parts of the Kaiparowits Plateau. Forms the Straight Cliffs, a nearly-vertical cliff face on the eastern margin of the Kaiparowits Plateau.	Light-yellow-gray to white, fine- to coarse-grained locally conglomeratic crossbedded sandstone in thick subparallel cliff-forming beds; thinner slope-forming beds of yellowish-gray, greenish-gray to dark-gray shale and mudstone; thin to thick beds of bituminous coal. 1,000 to 1,500 feet thick, thickening northwestward.	Yields small amounts of water to springs, generally less than 30 gallons per minute.
			Tropic Shale	Significant outcrop in the Cannonville-Henrieville-Tropic area and along the southern and eastern margins of the Kaiparowits Plateau.	Dark-gray calcareous marine shale; thin sandstone and siltstone beds near top and base; sparse white bentonite beds and nodular fossiliferous limestone in lower part. Weathers to slopes, intertongues with Straight Cliffs Formation. 500 to 900 feet thick.	Generally does not yield water.

Erathem	System	Series	Geologic unit		Principal locations of outcrop	Geologic characteristics	Hydrologic characteristics
Mesozoic	Cretaceous		Dakota Sandstone		Thin band of outcrop, generally less than 1 mile wide, along the southern and eastern margins of the Kaiparowits Plateau.	Cliff-forming layers of lenticular fluvial and littoral, crossbedded, reddish-brown, pale-brown, coarse-grained sandstone and quartzite, interbedded slope-, bench-, or niche-forming yellowish-gray to olive mudstone; dark-gray or brown carbonaceous shale and coal; local basal quartz-, quartzite-, and chert-pebble conglomerate. 0 to 250 feet thick.	Generally does not yield water.
	Jurassic	Upper	Morrison Formation		Significant outcrop along the southeastern margin of the Kaiparowits Plateau; thin band of outcrop along the eastern margin of the Kaiparowits Plateau.	Variegated continental beds of sandstone, conglomeratic sandstone, and bentonitic mudstone; coarser grained in lower part. 0 to 700 feet thick.	Do.
			Bluff Sandstone		Small area of outcrop east of the Kaiparowits Plateau. See footnote on plate 2.	Gray to red continental sandstone. Probably equivalent to the Salt Wash Member of the Morrison Formation.	Unknown.
			Winsor Formation		Significant outcrop southwest of Cannonville.	Gray to red continental sandstone and siltstone. Equivalent in places to Upper San Rafael Group and possibly Morrison Formation.	Do.
		Middle	San Rafael Group	Summerville Formation	Small area of outcrop east of the Kaiparowits Plateau.	Reddish- to pale-brown sandstone and dark-reddish-brown shaly siltstone in even, thin, alternating beds in northern part of area, becoming sandier and paler hued south of Collet Canyon. In the Straight Cliffs area the Summerville includes a tongue of greenish-gray to reddish-brown fine- to medium-grained, gritty, generally flat-bedded sandstone and mudstone, 0 to 140 feet thick. Erodes to ribbed cliffs, slopes, and niches. 0 to 200 feet thick, thinning southwestward by erosion.	Do.
				Entrada Sandstone	Significant outcrop east and southeast of the Kaiparowits Plateau.	Generally composed of three intergrading informal units of littoral origin and subequal thickness. Upper sandy unit: pale-gray yellowish-gray, and reddish-brown, fine-grained aeolian sandstone; thickly crossbedded in high-angle sets bounded by flat-truncation planes; cliff former. Middle silty unit: alternating thick sets of pale- to moderate-reddish-brown silty sandstone and dusky-red siltstone beds; marginal marine; slope former. Lower sandy unit: reddish-brown to pale-gray, fine-grained aeolian sandstone, commonly slumped at base in pipelike forms into underlying Carmel Formation. Forms cliffs and isolated buttes. The entire formation is more than 900 feet thick in northern part of area, thinning radially southward and eastward to 400 feet or less.	Yields small amounts of fresh water to wells in Escalante area, small amounts of reportedly poorer quality water to wells in Cannonville area, and water of unknown quality to wells in Glen Canyon City area.
				Carmel Formation	Significant outcrop south and east of the Kaiparowits Plateau, and south of the Cannonville-Henrieville area.	Thin beds of dusky-red limy siltstone, reddish-brown fine-grained friable sandstone, gray to pink limestone, and thin to thick beds of gypsum, all of marginal marine origin. Forms ledgy slopes. Limestone and gypsum content increases westward, as does total thickness, from about 200 feet to more than 900 feet.	Yields water to springs at contact of limestone-siltstone units near base of formation. Siltstone unit perches water in the limestone unit of the Carmel Formation, and severely inhibits downward movement of water to the Navajo Sandstone.

Table 1.--Description of geologic formations in the Kaiparowits Plateau area--Continued

Erathem	System	Series	Geologic unit		Principal locations of outcrop	Geologic characteristics	Hydrologic characteristics
Mesozoic	Jurassic	Middle	San Rafael Group	Page Sandstone	Combined with Navajo Sandstone.	Reddish-brown, moderate reddish-orange, and locally very light gray or grayish-pink fine-grained, well sorted sandstone, characterized by large-scale crossbedding. Crossbed sets generally range from 3 to 20 feet thick. Persistent layer of chert pebbles at the base or in the basal 6 inches.	Combined with Navajo Sandstone.
		Lower	Glen Canyon Group	Navajo Sandstone	Extensive outcrop both east and west of the Escalante River, on the southern margin of Boulder Mountain, in the middle reaches of the Paria River west of the East Kaibab monocline, in the lower reaches of the Paria River drainage, and on the Paria Plateau.	Gray and yellowish-gray, locally reddish-orange, thickly crossbedded, medium-to fine grained aeolian sandstone containing a few thin lenses, each less than 1 square mile in area, of dark-gray partly chertified magnesian limestone; conspicuous large-scale, trough-type crossbedding. Erodes to massive cliffs and domes. 0 to 1,900 feet thick, thickening uniformly from northeast to southwest.	Principal aquifer in study area. Yields generally less than 10 gallons per minute to seeps and springs, usually at the base of crossbed sets, where formation is unfractured. Yields up to 200 gallons per minute where formation is fractured or faulted. Water is fresh except where artesian conditions exist, either naturally or as a result of raised water levels caused by the filling of Lake Powell. In those areas water is fresh to slightly saline.
	?	?					
	Triassic (?)	Upper (?)		Kayenta Formation	Significant outcrop in the Escalante River drainage, particularly in tributary drainages east of the Escalante mainstem. Limited outcrop in the middle and lower reaches of the Paria River and in Paria River tributary drainages west of the East Kaibab monocline.	Red-brown, reddish-orange, pale-gray, greenish-gray, and lavender fluvial sandstone, siltstone, shale, and minor shale-pellet conglomerate and freshwater limestone; erodes to cliffs and benches. Interfingers with overlying and underlying formations. Averages about 200 feet thick.	Generally less permeable than the overlying Navajo Sandstone and underlying Moenave Formation and Wingate Sandstone. Perches water in the Navajo Sandstone resulting in springs and seeps at the Navajo-Kayenta contact in parts of the canyon of the Escalante River.
				Moenave Formation	Limited outcrop in middle and lower reaches of the Paria River, and in tributary drainages to the Paria River west of the East Kaibab monocline.	Composed of two fluvial members: Springdale Sandstone Member; pale-reddish-brown, medium-grained, micaceous, cliff-forming sandstone and minor siltstone; and the underlying Dinosaur Canyon Sandstone Member; reddish-orange, coarse- to fine-grained, parallel-bedded, ledge- and slope-forming friable sandstone, siltstone, and mudstone. The Moenave thins from nearly 400 feet thick in the southwest part of the study area to a wedge of irregular trace in the vicinity of The Rincon.	Yields water to wells on the Paria Plateau.
	Triassic	Upper		Wingate Sandstone	Limited outcrop in the Escalante River drainage, particularly in tributary drainages east of the Escalante mainstem.	Reddish-brown, light-brown, grayish-orange, fine-grained, thickly crossbedded, calcareous aeolian sandstone. Erodes to vertical cliffs commonly coated with dusky-red desert varnish. About 275 feet thick in most of study area; thins to a wedge edge near southwest corner of study area.	No wells utilize the Wingate and only one spring discharges from the Wingate in the study area.
			Chinle Formation		Limited outcrop on the flanks of the Circle Cliffs, on the southern margin of the Vermillion Cliffs, and in the middle and lower reaches of the Paria River.	Varicolored beds of fluvial and lacustrine origin; generally sandy at top; limy, muddy, and bentonitic in the middle; sandy and conglomeratic near base. 500 to 900 feet thick, thickening southward.	Unknown.
				Shinarump Conglomerate	Limited outcrop on the southern, western, and northeastern flanks of the Circle Cliffs, and on the southern margin of the Vermillion Cliffs.	Yellowish-gray, pale-brown, or gray-green medium-grained to conglomeratic fluvial sandstone; contains quartz pebbles, carbonized plant debris, and fragmental silicified wood; erodes to cliffs. 0 to about 200 feet thick in some deep channels.	Do.
		Middle (?) and Lower	Moenkopi Formation		Extensive outcrop in the Circle Cliffs, significant outcrop at the southern margin of the Vermillion Cliffs.	Fine-grained red beds and thin marine limestone and evaporite tongues. 250 to 1,000 feet thick, thickening uniformly northwestward.	Do.

Erathem	System	Series	Geologic unit	Principal locations of outcrop	Geologic characteristics	Hydrologic characteristics
Paleozoic	Permian	Lower	Kaibab Limestone	Significant outcrop at southern margin of the Vermillion Cliffs.	Grayish-yellow, fossiliferous, cherty, thin- to thick-bedded dolomitic limestone and interbedded light-gray to brown siltstone and sandstone. 0 to 60 feet thick in Circle Cliffs, 100 to 400 feet thick in remainder of study area, thinning southward.	Unknown.
			Toroweap Formation	Minor outcrop in Kaibab Gulch west of the East Kaibab monocline.	Yellowish-gray, white, and reddish-brown fine- to medium-grained crossbedded and gnarly-bedded sandstone, dark-red siltstone, and light-gray cherty limestone. Conditions of deposition similar to Kaibab Limestone. 200 to 400 feet thick.	Do.
			Hermit Shale	Minor outcrop in Kaibab Gulch west of the East Kaibab monocline.	Deep-red shale, siltstone, and shaly siltstone, sparse lenticular sandstone near base; locally shale contains mud cracks and ripple marks. 125 to 250 feet thick.	Do.

The generally small permeability of the Kayenta Formation is illustrated in the Escalante Canyon, where water discharges from the canyon wall at the Navajo Sandstone-Kayenta Formation contact at general location (D-36-6). A further illustration is spring (D-36-6)27bab-S1 in Harris Wash, which discharges approximately 7.5 gallons per minute at the Navajo-Kayenta contact.

The Navajo Sandstone is a very fine- to fine-grained, aeolian, crossbedded, quartzose sandstone. The Navajo is characterized by large-scale, high-angle crossbedding in sets generally from 20 to 50 feet thick, and is a cliff-forming formation. Color varies from nearly white to deep reddish-brown. An outcrop of Navajo Sandstone near Boulder is shown in figure 3.

The Page Sandstone is a moderate reddish-brown, moderate reddish-orange, and locally very light gray or grayish-pink, fine-grained, well-sorted sandstone (Peterson and Pipiringos, 1979, p. 21). It is characterized by large-scale crossbedding, with sets generally ranging from 3 to 20 feet thick. Angular chert pebbles generally less than 0.5 inch long commonly are present at the base or in the basal 6 inches of the formation. The Page Sandstone is hydrologically connected to the Navajo Sandstone, and is informally grouped with the Navajo in this report.

The Carmel Formation is of marginal marine origin, consisting of thin beds of dusky-red limy siltstone, reddish-brown friable sandstone, gray to pink limestone, and beds of gypsum. A siltstone bed at the base of the Carmel generally effectively inhibits movement of water between the Carmel and the underlying Navajo Sandstone. At several locations in the Kaiparowits Plateau area, water seeping down through the Carmel is diverted laterally by this siltstone bed and is discharged as springs--usually within about 10 feet of the top of the Navajo. Examples of such springs are listed in table 2.

The Entrada Sandstone is divided into three informal units. The upper and lower units are pale-gray to reddish-brown, fine-grained, cliff-forming aeolian sandstones. The middle unit consists of alternating thick beds of pale to reddish-brown, silty sandstone and dusky-red siltstone.

Structure

The major structural features in the Kaiparowits Plateau area are the Kaiparowits basin in the center of the area, the Kaibab upwarp to the west of the Kaiparowits basin, and the Circle Cliffs upwarp to the east (pl. 2).

The East Kaibab monocline separates the Kaibab upwarp and the Kaiparowits basin. The monocline dips steeply to the east, as much as 86 degrees. To the west in the Kaibab upwarp, the Navajo Sandstone is either absent (older rocks are at the surface) or at the surface. To the east in the Kaiparowits basin, the Navajo is buried by as much as 4,500 feet of younger sedimentary rocks, and rocks of Cretaceous age are at the surface. The Kaiparowits basin is asymmetrical, with a steeply eastward-dipping limb on the west--the East Kaibab monocline--and a much more gently westward-dipping east limb.

The Navajo Sandstone is intensely fractured along the East Kaibab monocline (fig. 4). The secondary porosity resulting from the fracturing probably enables the Navajo to accept a large percent of precipitation in the area as recharge. For open fractures, Craft and Hawkins (1959, p. 283) report

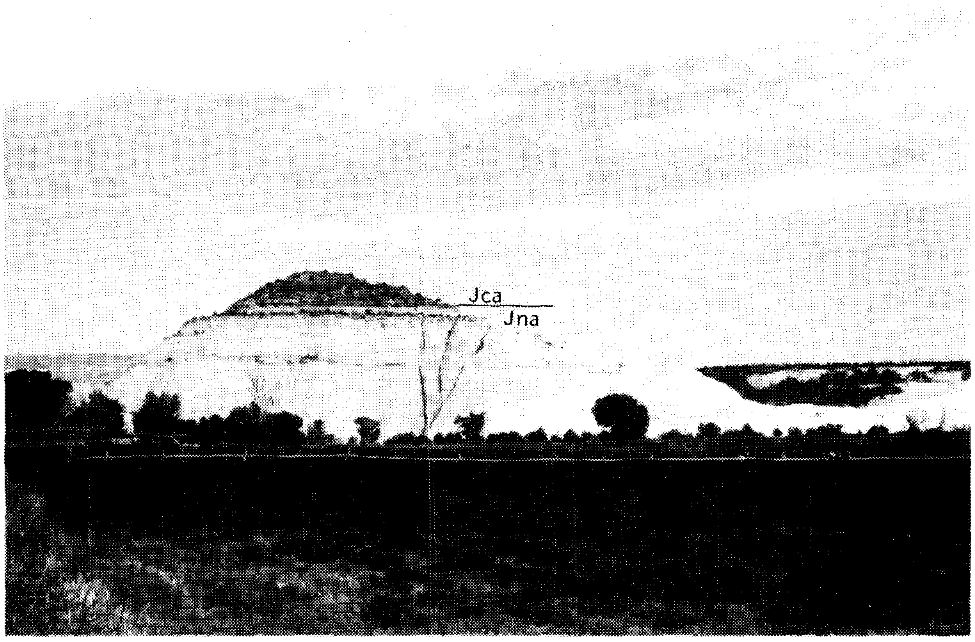

Figure 3.—Navajo Sandstone (Jna) overlain by Carmel Formation (Jca) at location (D-33-4)36, 1.5 miles south of town of Boulder, Utah.

Figure 4.– Fractured Navajo Sandstone in the East Kaibab monocline at location (C-42-2)25.

Table 2.--Selected springs that discharge from the Carmel Formation above basal siltstone of low permeability

Number: See "Numbering system for hydrogeologic-data sites", p. 5, and figure 2.

Number	Drainage	Name of spring	Altitude of land surface (feet)
(C-40-3) 5bab-S1	Park Wash	Adams Spring	6,270
(D-39-7) 8ddd-S1	Big Hollow Wash tributary	Liston Seep	4,550
16abd-S1	Coyote Gulch	--	4,560
(D-40-8) 17dca-S1	Sooner Wash	Sooner Water	4,250
27cbc-S1	Willow Gulch	--	4,210
(D-41-8) 2dab-S1	Fiftymile Creek	Soda Spring	4,270

that a 0.001-inch wide fracture will have a permeability of 54,000 millidarcies, or a hydraulic conductivity of about 132 feet per day. This value is in the range of two orders of magnitude greater than the hydraulic conductivity of unfractured Navajo Sandstone determined from laboratory analyses of Navajo cores (table 3).

The Circle Cliffs upwarp is an asymmetrical, elongate structural dome that has a gently westward-dipping west limb and a much more steeply eastward-dipping east limb. Near the axis of the Circle Cliffs upwarp, northeast of the Escalante River, the Navajo Sandstone has been removed by erosion and older rocks are at the surface. To the west of the axis of the upwarp, however, the Navajo is widely exposed.

HYDROLOGIC SETTING

Hydrologic Budget of the Kaiparowits Plateau Area

Ronald L. Jensen (U.S. Bureau of Reclamation, written commun., 1972) estimated a hydrologic budget for the Escalante River, Paria River, and Wahweap Creek basins as part of a regional reconnaissance of water resources in south-central Utah. Jensen's Wahweap Creek basin includes all of the drainages between the Escalante and Paria Rivers, and Jensen's three-basin area coincides with the area described in this report. Estimations by Jensen include precipitation, runoff, evapotranspiration, and potential ground-water recharge for each basin. Values for each of the three basins and for the entire study area are given in table 4.

Table 3.--Hydrologic and physical characteristics of shallow core and outcrop samples determined from laboratory analyses

[Abbreviations used in column headings are as follows: ft/d, feet per day; mm, millimeters; ft, feet; ft^2/d, feet squared per day.]

Location: See "Numbering system for hydrogeologic-data sites", p. 5, and figure 2.
Hydraulic conductivity: See p. vi. Distilled water used in hydrologic analyses
Porosity: See p. vi.
Grain-size distribution: Median diameter = d_{50}.
Sorting coefficient = $\sqrt{Q_3/Q_1}$, where Q_3 = 25 percent quartile, Q_1 = 75 percent quartile.
Total or saturated thickness of Navajo Sandstone: Saturated thickness of Navajo Sandstone used where information is available, otherwise total thickness used.
Estimated transmissivity: ft^2/d rounded to nearest 1,000; determined by multiplying horizontal hydraulic conductivity times saturated thickness of the Navajo Sandstone, or total thickness where saturated thickness is unknown.

Location	Hydraulic conductivity (K) Horizontal (ft/d)	Hydraulic conductivity (K) Vertical (ft/d)	Ratio horizontal/vertical K	Porosity (percent)	Grain-size distribution Median diameter (mm)	Grain-size distribution Sorting coefficient	Total (T) or saturated (S) thickness of Navajo Sandstone at site (ft)	Estimated transmissivity (ft^2/d)
				Navajo Sandstone				
(C-39-2) 5dc[1]	0.64	0.41	1.56	23.2	0.144	1.534	2,300(T)	1,500
(D-34-3)32ac[1]	.38	.22	1.72	25.6	.104	1.093	1,200(T)	500
(D-35-4) 1da[1]	--	1.36	--	20.9	.112	1.140	1,200(T)	[2]2,200
(D-36-6)18bbb	--	4.66	--	26.5	.178	1.638	<600(T)	[2]3,700
(D-39-8)23ac	2.12	2.10	1.01	28.3	.155	1.266	<1,200(T)	2,500
(A-41-8)23dcd (Arizona)	9.57	8.86	1.08	30.8	.208	1.209	1,200(S)	11,500
				Entrada Sandstone				
(D-35-3) 8aaa	0.67	0.27	2.48	22.2	0.188	1.408	--	--
(D-40-8) 7aca	1.20	.79	1.52	26.0	.151	1.430	--	--
(D-43-3)30dac	.01	.09	.11	--	.183	1.483	--	--
				Wingate Sandstone				
(D-34-5)12dbc	1.25	0.27	4.63	31.4	0.084	1.323	--	--
(D-36-7) 7aba3	1.17	.39	3.00	20.5	.099	1.250	--	--

[1]Outcrop sample collected and cored by Uygur (1980). Core directions are parallel and perpendicular to bedding planes. All other cores were obtained parallel and perpendicular to land surface.
[2]Horizontal hydraulic conductivity is unknown but is estimated by multiplying vertical hydraulic conductivity times 1.34.
[3]Outcrop sample (not shallow core).

Table 4.--Hydrologic budget of the Escalante River, Paria River, and Wahweap Creek basins (from Ronald L. Jensen, U.S. Bureau of Reclamation, written commun., 1972)

Basin	Acre-feet			
	Precipitation	Runoff	Evapotrans- piration	Potential ground-water recharge
Escalante River	1,389,500	86,000	1,271,000	32,500
Paria River	866,500	20,000	838,000	8,500
Wahweap Creek	709,000	16,000	690,000	3,000
Total	2,965,000	122,000	2,799,000	44,000

Estimation of the amount of precipitation falling in each basin was made by use of the State of Utah normal annual precipitation map (U.S. Weather Bureau, 1963). Areas between lines of equal normal annual precipitation were determined in each basin. The average value of adjacent isolines was then multiplied by the area between the lines, and all such determinations were summed for each basin.

Runoff was defined as the average annual flow at the mouth of each mainstem plus the amount of water diverted for irrigation, minus the amount of irrigation diversion return flow. Evapotranspiration, or consumptive use, was estimated by identification of plant communities and their areal extent and densities. The estimation was made from U.S. Geological Survey quadrangle maps and U.S. Forest Service timber-survey maps. Summer evapotranspiration (May-September) was defined as the sum of summer precipitation plus soil-moisture depletion minus summer runoff. Winter evapotranspiration (October-April) was defined as sublimation of any snowpack present.

Potential ground-water recharge was estimated as total precipitation minus the sum of total evapotranspiration plus runoff. The value is not limited to the Navajo Sandstone, but is for recharge to all ground-water reservoirs, both consolidated and unconsolidated. The annual amount of water available for recharge in the study area was estimated to be about 44,000 acre-feet.

Precipitation

Normal annual precipitation varies widely in the study area, from less than 6 inches along the Colorado River near Page, Arizona, to greater than 30 inches on the summit of Boulder Mountain. Normal May through September precipitation ranges from less than 3 inches near Page to more than 10 inches at the summit of Boulder Mountain (pl. 1).

Precipitation amounts increase with altitude. For example, at Boulder the normal annual precipitation is 12 inches and normal May through September precipitation is 6 inches, compared with 30 inches and 10 inches at the summit of Boulder Mountain. Boulder is located only 12 miles south-southeast of the Boulder Mountain summit. The altitude at Boulder is about 6,400 feet, whereas the altitude at the summit of Boulder Mountain is 11,328 feet. The temporal distribution of precipitation also changes with altitude. Only one-third of the total annual precipitation falls in the summer at the summit of Boulder Mountain, while 50 percent falls during May through September at the town of Boulder. This relationship of an increased percentage of total precipitation falling from October through April at higher altitudes exists throughout the study area.

Summer precipitation characteristically is in the form of intense and very localized thunderstorms of short duration. The intensity and short duration allows little time for precipitation to enter the ground-water system. Most of the water moves overland and becomes part of the surface-water system.

Winter precipitation occurs over larger areas, is much less intense, and of longer duration. It primarily falls in the form of snow and at higher altitudes may remain as snowpack for several months. Gradual warming and slow melting of the snowpack in the spring allows much more time for infiltration than is the case for summer precipitation. Runoff and infiltration characteristics resulting from spring and fall precipitation are transitional between those of summer and winter.

Surface-Water Conditions

Three stream-flow gaging stations are presently (1982) in operation in the Kaiparowits Plateau area--Pine Creek near Escalante, Escalante River near Escalante, and Paria River at Lees Ferry. Formerly several additional continuous-discharge measurement stations as well as annual peak-discharge measurement stations were in operation. All stream-flow gaging stations in the study area, both active and discontinued, are shown on plate 1 and listed in table 5.

Average annual discharge of surface water from the Escalante River basin for 5 years of record (October 1950-September 1955) at station 09339500, Escalante River at mouth, was 61,670 acre-feet. The majority of discharge originates in the upper basin near Boulder Mountain. Two areas that comprise only 331.4 square miles of the 1,770 square miles in the basin contributed 28,030 acre-feet, or about 45 percent of the annual discharge to the Escalante River basin. The areas are the upper reaches of the Escalante River upstream from station 09337500, comprising 310 square miles, and the East Fork of Boulder Creek upstream from station 09338000, comprising 21.4 square miles.

Table 5.--Selected streamflow data in the Kaiparowits Plateau area
[Abbreviations used in column headings are as follows: mi^2, square miles; ft^3/s, cubic feet per second; acre-ft/yr, acre-feet per year.]

Station number	Station name	Approximate drainage area (mi^2)	Period of record	Average discharge ft^3/s	Average discharge Acre-ft/yr	Average discharge Years	Extremes (ft^3/s) Maximum	Extremes Date	Extremes Minimum	Extremes Date
09335500	North Creek near Escalante	90	July 1950-Sept. 1955	7.64	5,530	5	3,610	8-21-52	0	(1)
09336000	Birch Creek near Escalante	36	July 1950-Sept. 1951; water years 1959-74[2]	.54	390	1	3,400	8-19-63	0	(1)
09336400	Upper Valley Creek near Escalante	53	Water years 1959-74[2]	--	--	--	5,560	8- 2-59	0	(1)
09336500	Birch Creek at mouth, near Escalante	100	Oct. 1951-July 1955	3.26	2,360	3	1,010	7-12-54	0.1	7-13-55; 7-14-55
09337000	Pine Creek near Escalante	78	July 1950-Sept. 1955; July 1957-Sept. 1982	4.55	3,330	30	1,010	8- 2-67	0	(1)
09337500	Escalante River near Escalante	310	Aug. 1909-Apr. 1913; Oct. 1942-Sept. 1955; Dec. 1971-Sept. 1982	15.0	10,870	26	3,450	8- -53	0.07	12-24-78
09338000	East Fork Boulder Creek near Boulder	21.4	July 1950-Sept. 1955; July 1957-Sept. 1972	23.7	17,160	20	483	5-20-64	8.2	11- 5-51
09338500	East Fork Deer Creek near Boulder	1.9	July 1950-Sept. 1955; water years 1959-74[2]	1.39	1,010	5	224	8- 3-61	0	2-10-53
09338900	Deer Creek near Boulder	63	Water years 1959-74[2]	--	--	--	3,820	8- 3-61	0	(1)
09339000	Boulder Creek near Boulder	175	July 1950-Sept. 1955	23.0	16,650	5	4,650	7-25-55	6.1	6-26-53
09339200	Twentymile Wash near Escalante	140	Water years 1959-68[2]	--	--	--	4,620	8-27-63	0	(3)
09339500	Escalante River at mouth, near Escalante	1,770	April 1950-Sept. 1955	85.2	61,670	5	14,600	8- 4-51	4.4	8-20-50; 7-11-51
09379800	Coyote Creek near Kanab	89	Water years 1959-73[2]	--	--	--	4,590	6-22-72	0	(3)
09379820	Buck Tank Draw near Kanab	5.3	Water years 1959-68[2]	--	--	--	190	7-30-67	0	(3)
09380380	Bryce Creek at Park Boundary, near Tropic	2.7	Water years 1965-66[2]	--	--	--	330	9- 5-65	0	(3)
09380400	Paria River at Cannonville	96	Water years 1959-62[2]	--	--	--	4,830	8- 3-61	0	(1)
09381000	Henrieville Creek near Henrieville	29	Aug. 1950-July 1955	5.17	3,740	4	3,360	7-31-53	0	11-22-52; 12-22-52
09381100	Henrieville Creek at Henrieville	34	Water years 1959-74[2]	--	--	--	7,360	8- 4-61	0	(1)
09381500	Paria River near Cannonville	220	Dec. 1950-Sept. 1955; water years 1959-74[2]	9.70	7,020	4	11,600	8-31-63	0	(1)
09381590	Sheep Creek at Park Boundary, near Cannonville	3.6	Water years 1965-66[2]	--	--	--	9.6	8- 2-66	0	(3)
09381600	Sheep Creek near Cannonville	17	Water years 1959-64[2]	--	--	--	1,260	8- 4-61	0	(3)
09381700	Sheep Creek Reservoir	31.1	Water years 1961-68[2]	--	--	--	4,620	8-31-63	0	(3)
09381800	Paria River near Kanab	668	Water years 1959-73[2]	--	--	--	15,400	8-31-63	0	(1)
09382000	Paria River at Lees Ferry	1,410	Oct. 1923-Sept. 1982	29.9	21,660	59	16,100	10- 5-25	1	(4)
10184000	Tropic and East Fork Canal (transmountain diversion from East Fork Sevier River)	--	Water years 1950-61	3.40	2,464	11	29	5-12-52	0	(5)

[1]Some flow throughout most years, but dry on occasions.
[2]Only annual-peak discharges gaged.
[3]Only intermittent or ephemeral flow.
[4]Most years prior to 1931.
[5]No flow for several months in each year.

Several ungaged tributaries on the southern flank of Boulder Mountain also contribute significant quantities of surface water to the Escalante River. Streamflow in Mamie, Sand, and Calf Creeks on October 21, 1981 were, respectively, 7.2, 10.0, and 6.4 cubic feet per second (table 6). Streamflow in the Escalante River just downstream from Calf Creek was 43.9 cubic feet per second.

Average annual discharge of surface water from the Paria River basin for 59 years of record (October 1923-September 1982) at station 09382000, Paria River at Lees Ferry, is 21,660 acre-feet. Two annual peak-discharge gaging stations are the only stations that have been installed in the Wahweap Creek basin. Both stations have been discontinued. The maximum recorded peaks during the respective periods of record are given in table 5.

A series of streamflow measurements was made along reaches of both the Escalante and Paria Rivers where the streambeds are incised in the Navajo Sandstone. The data were collected to determine whether the Navajo Sandstone contributes water to or receives water from the rivers. The measurements were made during October 21-23, 1981. Locations of the measurement sites are shown on plate 1, and the data are presented in table 6.

In the Escalante River basin, the reach just downstream from Pine Creek to Mamie Creek showed a gain in streamflow of 2.0 cubic feet per second, or an 11.9 percent increase, and the adjacent reach just downstream from Mamie Creek to Sand Creek showed a gain in streamflow of 1.5 cubic feet per second, or a 5.7 percent increase. For both reaches the total net gain was 3.5 cubic feet per second. This would be 2,500 acre-feet per year, assuming the net gain to be constant. No other reach of the Escalante River from Pine Creek to south of Harris Wash showed a change in streamflow of greater than 5 percent.

In the Paria River basin, streamflow in two reaches of the Paria River was measured. The first reach was from about 3 miles south of U.S. Highway 89 to the mouth of Kaibab Gulch. It showed a loss in streamflow of 2.0 cubic feet per second, or a 13.7 percent decrease. The second reach, from just below Kaibab Gulch south to the end of Navajo Sandstone outcrop (about 13 miles downstream from Kaibab Gulch) showed a gain in streamflow of 4.4 cubic feet per second, or a 33.9 percent increase. The net gain for both reaches was 2.8 cubic feet per second. This would be about 2,000 acre-feet per year, assuming the net gain to be constant.

The above measurements were made when the streamflow exceeded base flow for each stream, and the results need to be repeated at conditions nearer to base flow before they can be considered totally reliable. These data, however, indicate that in the area of potential recharge to the Navajo Sandstone in the upper reaches of the Escalante River, the Navajo also is discharging water to the river. In the Paria River basin, the adjacent reaches indicate opposite directions of movement; however, based on the data collected, the overall movement of water is from the Navajo Sandstone to the Paria River.

Gerald Plantz (U.S. Geological Survey, oral commun., 1982) made three streamflow measurements on the Paria River at U.S. Highway 89 on April 22 and August 25, 1981, and on March 4, 1982. These measurements were compared with recorded streamflow of the Paria River at Lees Ferry (station 09382000) for

Table 6.--Miscellaneous surface-water measurements in Escalante River and Paria River basins
[Abbreviations used in column headings are as follows: ft^3/s, cubic feet per second; umho/cm at 25°C, micromhos per centimeter at 25 degrees Celsius; mg/L, milligrams per liter.]

Dissolved solids: L, laboratory determination; other values calculated from specific conductance, (specific conductance times 0.61 in the Escalante River basin, and specific conductance times 0.73 in the Paria River basin)

Measurement location	Discharge (ft^3/s)	Discharge: Gain (+) or loss (-) (ft^3/s)	Discharge: Percent gain (+) or loss (-)	Specific conductance (umho/cm at 25°C)	Dissolved solids (mg/L)
10-21-81					
Escalante River near Escalante	16.8	--	--	--	--
Escalante River above Mamie Creek	18.8	+2.0	+11.9	850	484L
Mamie Creek at mouth	7.2			420	255
Escalante River above Sand Creek	27.5	+1.5	+5.7	680	415
Sand Creek at mouth	10.0			800	490
Escalante River above Calf Creek	36.2	-1.3	-3.5	730	450
Calf Creek at mouth	6.4			680	415
Escalante River above Boulder Creek	43.9	+1.3	+3.1	680	436L
Boulder Creek at mouth	41.2			280	172L
Escalante River above The Gulch	88.8	+3.7	+4.3	500	305
The Gulch	1.0			520	315
10-22-81					
Escalante River below The Gulch	78.9	--	--	--	--
Escalante River above Harris Wash	73.3	-6.6	-8.4	500	305
Harris Wash at mouth	5.9			700	425
Escalante River above unnamed tributary	78.9	-.3	-.4	510	318L
10-23-81					
Paria River 3 miles south of U.S. Highway 89	14.6	--	--	1,800	1,310L
Paria River above Kaibab Gulch	12.6	-2.0	-13.7	1,750	1,280L
Kaibab Gulch at mouth	.1			--	--
Paria River at mouth of Paria Canyon (south of terminous of Navajo Sandstone)	17.4	+4.7	+37.0	1,400	1,020
Paria River at Lees Ferry	16.6	-.8	-4.6	--	--
4-22-81					
Paria River at U.S. Highway 89	17.0	--	--	--	--
Paria River at Lees Ferry	29.2	+12.2	+71.8	--	--
8-25-81					
Paria River at U.S. Highway 89	9.1	--	--	--	--
Paria River at Lees Ferry	20.0	+10.9	+119.8	--	--
3-4-82					
Paria River at U.S. Highway 89	22.0	--	--	--	--
Paria River at Lees Ferry	33.6	+11.6	+52.7	--	--

the same dates. The Paria River gained 12.2, 10.9, and 11.6 cubic feet per second in the reach between U.S. Highway 89 and Lees Ferry on these dates, indicating substantial discharge from bedrock (mostly Navajo Sandstone) in the reach. Annual ground-water discharge from this reach, based on the average of the above measurements, is 8,400 acre-feet.

Water-quality samples were collected during the streamflow measurements made on October 21-23, 1981. The general trend of dissolved-solids concentration in the Escalante River was a decrease in a downstream direction to the mouth of Boulder Creek (table 6). The range was from 484 milligrams per liter upstream from Mamie Creek to 318 milligrams per liter about 5 miles downstream from Harris Wash.

The reaches of the Escalante River upstream from the section investigated flow over rocks younger than the Navajo Sandstone, primarily of Cretaceous age. Most contain soluble materials and contribute most of the dissolved solids in the Escalante River upstream from the Navajo outcrop area. Downstream from that point the water in the Escalante mainstem is diluted by tributary water with smaller dissolved-solids concentrations. The tributary waters have flowed across or through the Navajo or other formations that generally contain less soluble material than the rocks of Cretaceous age.

Boulder Creek significantly dilutes the dissolved-solids concentration of the Escalante River. During the October 21, 1981 streamflow measurements, Boulder Creek had a flow of 41.2 cubic feet per second into the Escalante River, which had a flow of 43.9 cubic feet per second just upstream from Boulder Creek. The dissolved-solids concentrations in Boulder Creek was 172 milligrams per liter; that of the Escalante mainstem was 436 milligrams per liter. Downstream from Boulder Creek, the concentration of dissolved solids in the Escalante River was 318 milligrams per liter, a 27 percent decrease.

There were no tributaries having a streamflow of greater than 0.1 cubic foot per second to the investigated reaches of the Paria River; however, the lower reach, from Kaibab Gulch to the southernmost extent of Navajo Sandstone outcrop, showed a gain in streamflow from 12.7 to 17.4 cubic feet per second, which indicates that the bedrock discharges water to the river in that reach. This indication is substantiated by dilution of Paria River water by fresher water from the Navajo Sandstone. The dissolved-solids concentration in the investigated reaches of the Paria River ranges from 1,310 milligrams per liter 3 miles south of U.S. Highway 89 to 1,020 milligrams per liter at the southernmost area of Navajo Sandstone outcrop.

Ground-Water Conditions

The Navajo Sandstone ranges from completely saturated and confined to completely unsaturated. Confined conditions exist in the Kaiparowits basin under the Kaiparowits Plateau and near the Paria River where it is crossed by U.S. Highway 89. The Navajo also is completely saturated in the lower Wahweap Creek area because of flow from Lake Powell into the aquifer. Unsaturated conditions are present along the southern margin of the Paria Plateau. Principal areas of withdrawal of water from the Navajo are in the Boulder, Paria Plateau, and Wahweap Bay areas.

In the Boulder area, the unsaturated thickness of the Navajo Sandstone ranges from 0 to nearly 450 feet, depending on the topography. Generally, less than 200 feet of the Navajo is unsaturated. The Navajo generally is at the surface except in canyons where it underlies stream-valley alluvium that was eroded and transported from Boulder Mountain. The total thickness of the formation in the area is unknown, but probably varies considerably as a result of differential erosion in canyons and uplands. The altitude of the base of the Navajo in the Boulder area also is unknown and difficult to infer because of tectonic activity associated with Boulder Mountain.

At well (D-35-4)20cca-1, near Escalante, the upper 550 feet of the Navajo is unsaturated. At well (D-40-8)7bdc-1, near Fortymile Creek in the Escalante River basin, only the upper 100 feet is unsaturated.

Information about water levels in the Navajo Sandstone under the Kaiparowits Plateau is scarce. Drillers' reports for 22 oil-test wells note that water is present in the Navajo; however, most of the 22 reports simply indicate "damp sand", "sand and water", or a similar indication of water, without reference to where in the Navajo section the condition was first penetrated. Generally, no water levels are given in the reports.

Less information is available about water in the Entrada Sandstone than in the Navajo. Water is withdrawn for irrigation or domestic use from several wells completed in the Entrada near the towns of Cannonville, Escalante, and Glen Canyon City. The Entrada is slightly less than 600 feet thick in the Glen Canyon City area, and about 400 feet of that thickness is saturated. Water levels have increased subsequent to the filling of Lake Powell, which began in 1962.

No water wells penetrate the Wingate Sandstone in the study area, and virtually no information exists regarding presence of water in that formation. Except on the flanks of the Circle Cliffs, the Wingate is overlain by the Kayenta Formation and the Navajo Sandstone. Generally, wells are not drilled into the Wingate because the Navajo or less deep aquifers yield water of adequate quantity and quality.

Hydrologic Characteristics of the Navajo, Entrada, and Wingate Sandstones

Hydrologic characteristics of the Navajo, Entrada, and Wingate Sandstones were determined from laboratory analyses of shallow core and outcrop samples. In addition, short-term aquifer tests were conducted using wells completed in the Navajo Sandstone at several locations in the study area.

Laboratory analyses of porosity, hydraulic conductivity, and grain-size distribution were conducted on 10 shallow core samples and on one outcrop sample. The results of the analyses are presented in table 3. For three samples collected and analyzed by Uygur (1980), (C-39-2)5dc, (D-34-3)32ac, and (D-35-4)1da, hydraulic conductivity was determined in directions parallel and perpendicular to bedding planes in the Navajo Sandstone. All other samples were collected by the author and analyzed by Core Laboratories, Inc., and hydraulic conductivity was determined in directions parallel and perpendicular to the land surface.

Comparison of the results of analyses for the Navajo, Entrada, and Wingate Sandstones (table 3) indicates, based on the small number of samples available, that hydraulic conductivity in the horizontal direction is about the same for all three formations. Hydraulic conductivity in the vertical direction is smaller in both the Entrada and Wingate than in the Navajo. The ratios of horizontal to vertical hydraulic conductivity for the Navajo, Entrada, and Wingate are, respectively, about 0.8 to 1, 1.5 to 1, and 3.6 to 1. The small differences between horizontal and vertical hydraulic conductivity of the formations, especially the Navajo and Entrada, indicates a strong tendency towards isotropism, and illustrates the small effect that bedding planes within cross-bed sets have on hydraulic conductivity.

Porosity is similar for all three formations, but the Wingate is finer grained than either the Navajo or Entrada. The Navajo is very fine- to fine-grained, the Entrada is fine-grained, and the Wingate is very fine-grained. The sorting coefficient is about the same for all three formations.

Similar analyses were performed on samples collected to the northeast in the lower Dirty Devil River basin (Hood and Danielson, 1981, p. 121), to the southwest and west in the upper Virgin River and Kanab Creek basins (Cordova, 1981, p. 22), and farther west in the central Virgin River basin (Cordova, 1978, p. 25). The results of analyses on samples from these areas and from the Kaiparowits Plateau area are summarized in table 7.

Horizontal and vertical hydraulic conductivity and median grain size all increase significantly from the northeast to the southwest. Porosity is about the same in all areas except in the central Virgin River basin, where it is markedly less. Sorting-coefficient values show no geographical trend.

Three short-term aquifer tests were conducted in the Kaiparowits Plateau area to determine transmissivity (T) and storage coefficient (S) of the Navajo Sandstone. The first test was near U.S. Highway 89 about 5 miles south of the Utah-Arizona border, the second was near the shore of Wahweap Bay, and the third was near the town of Boulder. The results of the tests are shown in table 8, and records of the wells used are given in table 12 (at back of report).

The test near U.S. Highway 89 was a two-well test, and determinations of transmissivity and storage coefficient were made from drawdown in the observation well by the type-curve matching method (Lohman, 1972, p. 15-18). The tests near Wahweap Bay and near the town of Boulder were both single-well tests, and transmissivity was determined by the straight-line solution method (Lohman, 1972, p. 19-21). Transmissivity for the three tests ranged from 5,700 to 7,000 feet squared per day. Storage coefficient determined from the test near U.S. Highway 89 was 0.0067.

In addition to the three short-term aquifer tests discussed above, a fourth longer-term aquifer test was conducted for Utah International Inc. by Bingham Engineering. The location is near Bald Knoll, 6 miles west of the western border of the Kaiparowits Plateau area. The results of the test are included because no aquifer-test data were collected within the boundaries of the study area near the test location, and the test is a 30-day test with a pumped well, (C-40-5)21abc-1, that is screened in about 83 percent of the Navajo. The transmissivity and storage coefficient values were determined by

Table 7.--Comparison of hydrologic and physical characteristics of the Navajo Sandstone and results of aquifer tests in the Kaiparowits Plateau area with those in the lower Dirty Devil River basin, the upper Virgin River and Kanab Creek basins, and the central Virgin River basin

[Abbreviations used in column headings are as follows: ft/d, feet per day; mm, millimeters; ft^2/d, feet squared per day.]

Hydraulic conductivity: See p. vi.
Porosity: See p. vi.
Median grain size = d_{50}.
Sorting coefficient = $\sqrt{Q_3/Q_1}$, where Q_3 = 25 percent quartile, Q_1 = 75 percent quartile.
Transmissivity: See p. vi.
Storage coefficient: See p. vi.

Basin or study area	Hydraulic conductivity (ft/d) Horizontal		Vertical		Porosity (percent)		Median grain size (mm)		Sorting coefficient		Aquifer-test results Transmissivity (ft^2/d)		Storage coefficient	
	mean	median	mean	median	mean	median	mean	median	mean	median	mean	median	mean	median
Lower Dirty Devil River	0.16	0.05	0.56	0.052	25.6	24.8	0.15	0.12	1.4	1.5	1,580	1,540	0.0013	0.0015
Kaiparowits Plateau area	3.18	1.38	2.94	1.73	25.9	26.1	.15	.15	1.3	1.3	9,050	6,850	.0044	.0045
Upper Virgin River and Kanab Creek	3.35	3.84	3.06	3.38	25.7	27.2	.19	.16	--	--	7,200	5,600	.0016	.0012
Central Virgin River	--	--	--	--	32	34	.18	.17	1.4	1.4	4,100	5,000	.04	.04

Table 8.--Results of aquifer tests in and near the Kaiparowits Plateau area

[Abbreviations used in column headings are as follows: gal/min, gallons per minute; ft, feet; ft^2/d, feet squared per day; gal/min/ft of drawdown, gallons per minute per foot of drawdown.]

Well number: See "Numbering system for hydrogeologic-data sites", p. 5, and figure 2.
Transmissivity: See p. vi.
Storage coefficient: See p. vi.

General area	Date	Length of test (hours)	Test well Number	Use	Pumping rate (gal/min)	Penetration of saturated Navajo Sandstone thickness Depth (ft)	Percent	Transmissivity (ft^2/d)	Storage coefficient	24-hour specific capacity (gal/min/ft of drawdown)
U.S. Highway 89, 5 mi south of Utah-Arizona border	Feb. 9-10, 1981	24	(A-41-8)14bca-1	pumped	57	300	18	--	--	10.0
			14bcb-1	observation		1,005	62	6,700	0.0067	
Near Wahweap Bay	Apr. 1, 1981	[1]3.75	(A-42-8)35dab-2	pumped	730	360	[2]20	7,000	--	--
Near the town of Boulder	Apr. 23-24, 1981	24	(D-33-4)35bbd-1	pumped	410	340	[2]25-35	5,700	--	--
Near Bald Knoll[3]	Dec. 29, 1980 Jan. 4, 1981	151.5	(C-40-5)21abc-1	pumped	1,260	1,412	83	5,900	--	[4]15.4
			16cdc-1	observation		1,455	86	12,900	.0021	
			21abb-1	observation		564	33	16,100	.0045	

[1]Test scheduled for 24 hours, but pump shut down at 3.75 hours.
[2]Estimated.
[3]About 6 mi west of study area. Not shown on plate 1.
[4]Specific capacity calculated from drawdown after 49.7 hours of pumping.

the author of this report from data collected by Bingham Engineering. The saturated thickness of the Navajo is about 1,705 feet, and the pumped well is screened in 1,412 feet of that thickness. Analysis of the test was conducted using data from the first 151.5 hours. At that time, an unscheduled pump shutdown occurred for a period of 16 hours.

Two observation wells were used, one 300.77 feet and the other 1,671.16 feet from the pumped well. Transmissivity for the pumped well was determined from drawdown data by the straight-line solution method (Lohman, 1972, p. 19-21), and transmissivity and storage coefficient for the observation wells were determined from drawdown data by the type-curve matching method (Lohman, 1972, p. 15-18). Results are shown in table 8. Transmissivity ranged from 5,900 to 16,100 feet squared per day and storage coefficient ranged from 0.0021 to 0.0045.

The values obtained for transmissivity and storage coefficient from the aquifer tests are subject to a degree of inaccuracy because of deviation from established test criteria. The most significant deviation is a lack of complete penetration of the aquifer by the pumped wells. The percent penetration of the pumped wells in the three tests conducted in the study area ranges from 18 to 35 percent, and the pumped well in the test conducted near Bald Knoll is open to 83 percent of the saturated thickness of the Navajo. No attempt was made to adjust values of tranmissivity to account for partial penetration of the saturated thickness of the aquifer.

Other factors affect the results of individual tests. The test near Wahweap Bay had a constant head-boundary because Lake Powell is approximately 0.25 mile northeast of the pumped well. In addition, the accuracy of water-level measurements obtained in the pumped well during pumping in both the tests near Wahweap Bay and Boulder is questionable because of possible leakage from the pump column. Precise measurements could not be obtained with a steel tape and measurements with an electric tape were erratic. Because of this problem, drawdown curves could not be plotted, and hence recovery data is based only on relative changes in water levels during recovery, and not on recovery from a measured drawdown.

The result of the inability to base recovery from a measured drawdown curve is a less-than-actual amount of recovery; and a larger-than-actual value for transmissivity is obtained if steady-state conditions have not been re-established. Steady-state conditions probably had not been re-established by the conclusion of pumping because even 24 hours of pumping, as in the test near Boulder, usually is insufficient time to re-establish equilibrium in the Navajo Sandstone ground-water system, and the calculated transmissivity probably is too large.

The test near Bald Knoll produced transmissivity values at the two observation wells in reasonably good agreement with each other; however, the value obtained at the pumped well was only one-third to one-half of those obtained at the observation wells. A possible cause for the smaller transmissivity of the pumped well is a variation in the local geology. Stokes (1964) indicates a significant fault with considerable offset in the general area of the test. Because of the scale (1:250,000) of the geologic map by Stokes, precise location of the fault is difficult; however, it appears to pass directly through the location of the pumped well and the proximal observation well. On a 1:24,000 scale map, Goode (1973) shows a fault about 0.5 mile east and another less than 2 miles west of the three wells used in the aquifer test.

Results of aquifer tests outside the study area indicate a less clear northeast-to-southwest increase in transmissivity and storage coefficient than is the case for hydraulic conductivity and grain size determined from shallow cores and outcrop samples (table 7). Transmissivity in the lower Dirty Devil River basin (Hood and Danielson, 1979, p. 22-23) is less than that in the Kaiparowits Plateau area; however, transmissivities in the central Virgin River basin (Cordova, 1978, p. 27) and in the upper Virgin River and Kanab Creek basins (Cordova, 1981, p. 24) also are less than in the Kaiparowits Plateau area. Storage coefficient is less in the lower Dirty Devil River basin and greater in the central Virgin River basin than in the Kaiparowits Plateau area, but it is about the same in the upper Virgin River and Kanab Creek basins as in the Kaiparowits Plateau area.

In addition to transmissivity values obtained from aquifer tests, values for transmissivities of the Navajo Sandstone in the Kaiparowits Plateau area have been estimated from the laboratory hydraulic conductivities of the six shallow core samples. This estimation was made by multiplying the laboratory horizontal hydraulic conductivity by the saturated thickness of the Navajo in the area where each core sample was collected. Results are shown in table 3.

Where the horizontal hydraulic conductivity is unknown, it has been estimated by multiplying the vertical hydraulic conductivity by 1.34, the average ratio of horizontal-to-vertical hydraulic conductivity for the sites where both values are known. Where the saturated thickness is unknown, the total thickness of the Navajo has been assumed to be saturated. This assumption leads to overestimates of transmissivity, but indicates possible maximum values.

Except at location (A-41-8)23dcd, the estimated values for transmissivity were less than any of the values calculated from aquifer tests. Smaller values are to be expected because the transmissivity values determined from core samples exclude the effects of secondary porosity resulting from fracturing of the aquifer. The core samples are integral rock specimens, whereas the aquifer tests are a direct, in situ evaluation of the aquifer's gross hydrologic characteristics.

The results of the core analyses and aquifer tests as well as the estimated transmissivities from core analyses all indicate a wide range in hydraulic conductivity and transmissivity in the Navajo Sandstone in the Kaiparowits Plateau area. The values given in this report need to be used with caution: they indicate a general range of values in the area and may not be applicable to specific locations. The actual hydrologic properties of the Navajo in any given area can be determined only from detailed site-specific investigations.

GROUND WATER IN THE NAVAJO SANDSTONE

Recharge

Recharge to the regional ground-water system of the Navajo Sandstone primarily takes place in three areas--the southern flank of Boulder Mountain, the Paria Plateau, and the outcrop area west of the Kaiparowits Plateau. Recharge in these areas primarily is by infiltration of precipitation directly into the fractured Navajo outcrop or into the Navajo from overlying unconsolidated deposits.

The hydraulic gradient in the Boulder Mountain area is to the south away from Boulder Mountain, and the hydraulic gradient in the Paria Plateau area is to the northeast away from the Paria Plateau (fig. 5). In both locations the area of Navajo Sandstone outcrop is large, and on the Paria Plateau additional areas of Navajo Sandstone are covered by a veneer of dune sand. The southern flank of Boulder Mountain is covered by thick deposits derived from both glacial and fluvial activity. Most of the precipitation on Boulder Mountain occurs in winter, and the combination of the thick unconsolidated deposits and slow rate of runoff from melting snowpack allows sufficient time for water to percolate into the Navajo.

The hydraulic gradient in the Navajo outcrop area west of the Kaiparowits Plateau could not be determined because of insufficient water-level data; however, the outcrop area is large and is in an area of intense fracturing (fig. 4). The fracturing probably has caused significant secondary porosity. Goode (1966, p. 28) characterizes the area as a "tremendous recharge area".

In the Paria Plateau area, the Navajo Sandstone also is recharged by upward leakage from the underlying Kayenta Formation. At the southwestern margin of the Paria Plateau, the water table is in the Kayenta and the underlying Moenave Formation, and the Navajo is unsaturated. To the north, the lower part of the Navajo is saturated, and farther north where the Paria River is crossed by U.S. Highway 89, the Navajo is fully saturated and confined. The hydraulic gradient to the northeast is less than the regional northeast dip of the geologic strata.

Probable methods of recharge to the Navajo Sandstone in other parts of the study area are by downward leakage from the overlying Carmel Formation or from overlying saturated alluvium. Recharge also may occur by seepage into the Navajo from streams where the altitude of the water table is lower than the streambed, but this condition could be confirmed in only one reach of the Paria River.

Areas of downward leakage from the Carmel Formation into the Navajo (Page) Sandstone have not been located, but it is likely that the process takes place in the western part of the study area, most probably in areas where structural deformation has caused fracturing in the Carmel, or where ground-water movement has caused dissolution of salts in the Carmel. Either of the above situations could allow water to move from the Carmel into the Navajo.

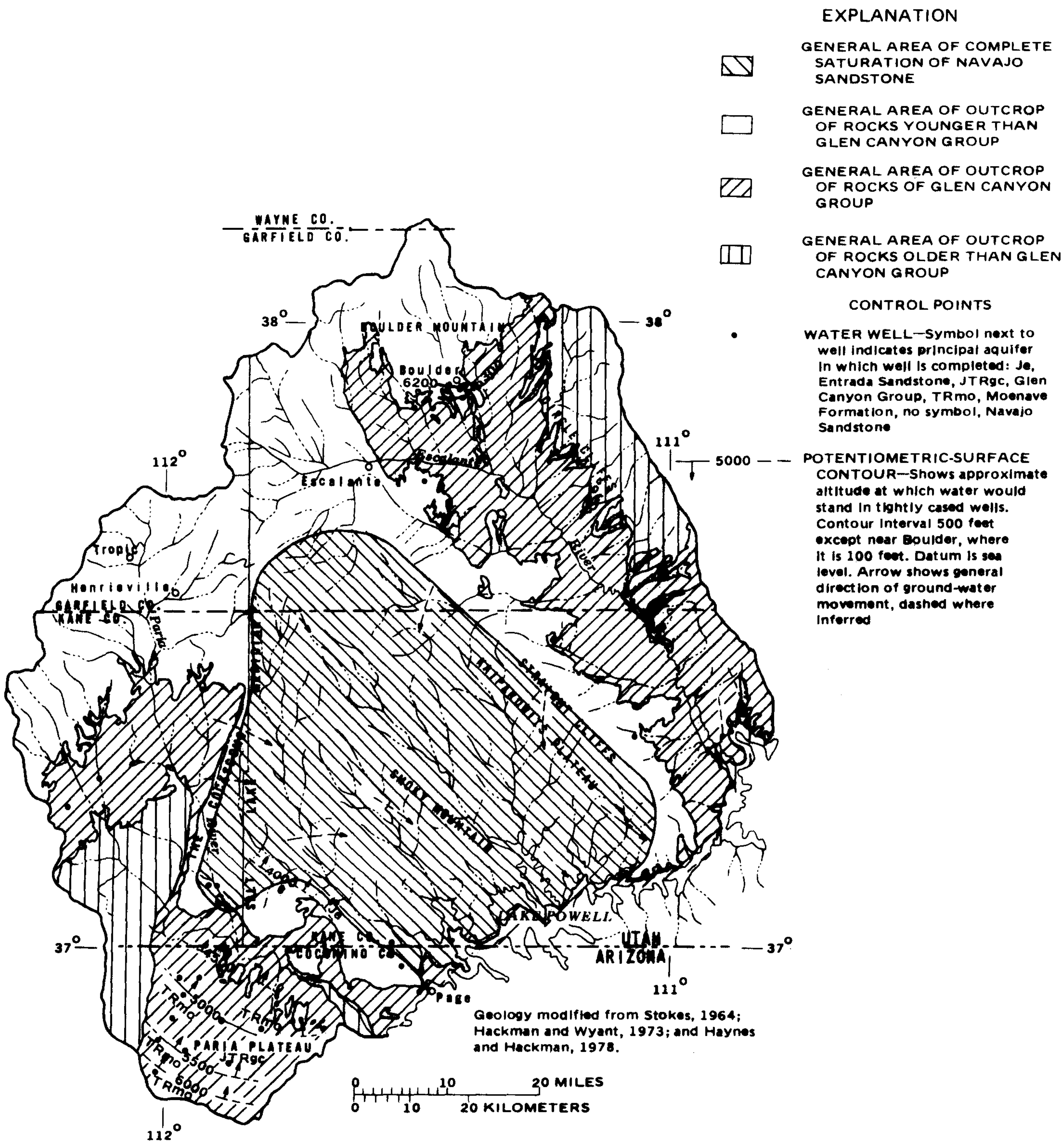

Figure 5.—Approximate potentiometric surface and general direction of movement of water in the Navajo Sandstone and related formations.

Several locations indicate that the permeability of the undisturbed basal siltstone unit of the Carmel Formation is sufficiently small to effectively perch ground water and greatly inhibit downward leakage into the Navajo Sandstone. Five springs along the Hole-in-the-Rock Road in the Escalante River basin as well as Adams Spring in the Paria River basin all discharge from a limestone unit in the Carmel directly above the basal siltstone (table 2). These examples indicate that where the basal siltstone unit of the Carmel is present and unfractured, downward leakage into the Navajo is greatly inhibited.

Downward leakage from overlying saturated alluvium takes place in canyon bottoms of tributaries of both the Escalante and Paria Rivers. A number of springs in the canyons discharge from alluvium and are the result of the inability of the Navajo Sandstone to accept all the available water from the alluvium. Commonly the alluvium has been derived from the Navajo, is sandy in nature, and has a large porosity. Todd (1959, p. 16) indicates a porosity of 30 to 40 percent for such material. Because of the large porosity, the sand provides an effective "holding reservoir" to retain runoff for eventual seepage to the Navajo.

Areas where sandy alluvium overlies the Navajo Sandstone are numerous, but most are small compared with the outcrop area of the Navajo; however, they probably contribute a significant part of the recharge in the southern part of the study area. The precipitation there is primarily in the form of summer storms, and direct infiltration of water into Navajo outcrop is limited because of its small permeability.

Movement

Movement of ground water in the Navajo Sandstone generally is toward the central part of the Kaiparowits Plateau from the principal recharge areas--to the northeast from the Paria Plateau, to the south from the Boulder Mountain area, and to the east from the area west of the Kaiparowits Plateau (fig. 5). Subsequent movement of ground water under the Kaiparowits Plateau is to the southeast toward Glen Canyon and Lake Powell. There probably are some local variations in the direction of movement caused by local geologic structure and by discharge to the Escalante and Paria Rivers.

Presently (1982) there is a reversal of the pre-Lake Powell gradient for several miles inland from the lake. The original gradient toward Glen Canyon still exists regionally, however, and when equilibrium is re-established in the ground-water system, the reversed gradient along the lake shore probably will no longer exist (see section on Effects of Lake Powell).

Discharge

Discharge from the Navajo Sandstone occurs by springs and seeps (including seepage to stream reaches), wells, evapotranspiration, upward leakage into the overlying Carmel Formation, and downward leakage into the underlying Kayenta Formation. During this study, an on-site inventory was made of most springs shown on U.S. Geological Survey 7 1/2- and 15-minute quadrangle maps and that appear to discharge from the Navajo Sandstone. The water sources identified as springs on the maps generally fall into three categories: (1) Natural surface-water impoundments caused by depressions in the surface of the Navajo (these are not really springs); (2) water discharging from alluvium overlying the less-permeable Navajo; and (3) seeps discharging from perched zones in the Navajo. Few springs discharge from the main zone of saturation in the Navajo Sandstone. Records of selected springs from categories 2 and 3 are given in table 9.

The natural surface-water impoundments caused by depressions in the surface of the Navajo Sandstone create small reservoirs which provide water for limited local use, but the water in the impoundments is not discharged from the Navajo. Where alluvium overlies the less-permeable Navajo, the Navajo cannot accept water from the alluvium as rapidly as the alluvium gains water during precipitation, and water is discharged at the alluvium-Navajo contact. Discharge is from the alluvium, not from the Navajo, and water is perched in the alluvium by the Navajo. Seeps discharging from perched zones in the Navajo mainly are present along canyon walls in the southern reaches of the Escalante River drainage. Water usually oozes rather than flows and generally the discharge is at the contact between cross-bed sets in the Navajo. The amount of discharge typically is large enough to support some plant life, and at the larger seeps some water moves down the canyon walls. Typically, the seeps are located high on canyon walls, and the water is evaporated prior to reaching the canyon floors. A seep in the canyon of Fiftymile Creek at location (D-40-8)24 is shown in figure 6.

Cooley (1965) conducted a reconnaissance of Glen Canyon and tributary canyons prior to inundation of the area by Lake Powell. The reconnaissance included canyons of the lower reaches of the Escalante River and of streams tributary to the Colorado River between the Escalante and Paria Rivers. In the Kaiparowits Plateau area, Cooley located 76 springs discharging from the Glen Canyon Group (the Navajo Sandstone, the Kayenta Formation, and the Wingate Sandstone). The total discharge from the 76 springs was estimated to be 924 gallons per minute. Assuming constant discharge, total annual discharge would have been 1,490 acre-feet per year.

Presently (1982), 40 of the 76 springs are below the surface of Lake Powell. These 40 springs accounted for 681.5 gallons per minute, or 74 percent of the 924 gallons per minute reported by Cooley (1965). The remaining 36 springs had a discharge of 242.5 gallons per minute.

Of the 36 springs in the Glen Canyon Group above the water level of Lake Powell, only 6 had estimated discharges of greater than 5 gallons per minute, and only 1 had an estimated discharge of greater than 10 gallons per minute. The six springs with discharges of greater than 5 gallons per minute were inventoried during this study. Springs (D-41-9)8cdc-S1 and (D-41-9)29aaa-S1 appear to be discharging from sandy alluvium overlying the Navajo Sandstone. This water probably was originally recharged to the alluvium and not to the Navajo. Springs (D-41-9)21aab-S1 and (D-42-8)26cdd-S1 discharge at contacts between cross-bed sets. The discharge point for (D-41-9)21aab-S1 is about 20 feet above the level of Lake Powell, and the discharge point for (D-42-8)26cdd-S1 is about 150 feet above the reservoir surface. They are both more accurately described as seeps and apparently discharge from perched zones.

Table 9.--Records of selected springs discharging from the Navajo Sandstone or overlying alluvium
[Abbreviations used in column headings are as follows: ft, feet; gal/min, gallons per minute; °C, degrees Celsius; mg/L, milligrams per liter.]

Number: See "Numbering system for hydrogeologic-data sites", p. 5, and figure 2.
Discharge: E, estimated; M, measured.
Dissolved solids: C, calculated from specific conductance (specific conductance times 0.63).

Number	Name of spring	Subdrainage	Altitude of land surface (ft)	Date inventoried	Discharge (gal/min)	Temperature (°C)	Dissolved solids (mg/L)	Remarks
(C-38-1)33dca-S1	Round Valley Seep	Round Valley draw	6,140	5-28-74 6-19-81	0.25M No flow	16.0 --	310 --	Price, 1977b. Damp alluvium, small amount of standing water.
(C-40-1)11ddb-S1	Pump Canyon Spring	Cottonwood Creek	5,360	7-23-64 5-29-74 10-23-80	8M 15E 7.5M	16.5 15.0 9.0	165 140 285	Goode, 1966, table 2, no. 83. Price, 1977b.
14cbd-S1	--	do.	5,220	7-22-64 6-19-81	63M 60M	15.5 15.5	195 160	Goode, 1966, table 2, no. 85. Discharges from alluvium. Water probably originates from underlying Navajo Sandstone.
16cba-S1	--	Hackberry Canyon	5,260	7-21-64	10E	--	--	Goode, 1966, table 2, no. 81.
20ddd-S1	--	do.	5,210	7-21-64 11-15-81	2E No flow	-- --	-- --	Goode, 1966, table 2, no. 82. Damp alluvium and standing water. Probably perched by underlying Navajo Sandstone.
22ddb-S1	--	Cottonwood Creek	5,140	7-23-64 6-19-81	1-2E No flow	-- --	-- --	Goode, 1966, table 2, no. 88. Damp alluvium and large cottonwoods.
23bba-S1	Cottonwood Spring	do.	5,120	7-20-64 9-25-79	58M 60E	15.5 16.0	200 175	Goode, 1966, table 2, no. 86. Discharges from alluvium. Water probably originates from underlying Navajo Sandstone.
23bcb-S1	--	do.	5,180	7-23-64 6-19-81	2E No flow	18.5 --	-- --	Goode, 1966, table 2, no. 87. Damp alluvium and large cottonwoods.
23dbd-S1	--	do.		10-30-79	12M	10.5	280	Discharges from Thousand Pockets Tongue of Page Sandstone.
(C-40-2)29dcb-S1	--	Kitchen Canyon	5,430	--	--	--	--	Saturated alluvium. Water probably perched by underlying Navajo Sandstone. No access to spring. Located at bottom of Kitchen Canyon. Spring appears to be source of streamflow in Kitchen Canyon.
30cca-S1	--	Nipple Lake	5,550	6-12-81	No flow	--	--	Saturated alluvium at lake shore. Spring discharges to Nipple Lake.
30ccd-S1	--	do.	5,550	6-12-81	1E	--	--	Water seeping from saturated alluvium at lake shore. Spring discharges to Nipple Lake.
30cdc-S1	--	do.	5,550	6-12-81	--	--	--	Discharge forms 200 ft by 500 ft pool. Spring discharges to Nipple Lake.
33baa-S1	--	Kitchen Canyon	5,320	--	--	--	--	Saturated alluvium. Water probably perched by underlying Navajo Sandstone. No access to spring. Located at bottom of Kitchen Canyon. Spring appears to be source of streamflow in Kitchen Canyon.
(C-41-3)18acc-S1	Wildcat Spring	Deer Spring Wash	5,760	10- 9-81	1M	15.5	380C	Discharges from alluvium. Water probably perched by underlying Navajo Sandstone.
(C-41-4) 1bac-S1	Sand Spring	do.	5,920	6-14-81	1.5M	--	--	Do.
(D-34-3)13dc -S	--	Death Hollow	5,790	10-16-67	10E	16.5	230	Goode, 1969, table 1, no. 27. South side of canyon bottom, discharge spurts from Navajo Sandstone.
13dc -S	--	do.	5,790	10-16-67	8-10E	15.5	260	Goode, 1969, table 1, no. 28. North side of canyon bottom.
(D-35-6)21cca-S1	--	Horse Canyon	5,300	10-22-81	<1M	11.0	240C	Discharges from alluvium. Water probably perched by underlying Navajo Sandstone.
21ccd-S1	--	do.	5,250	10-22-81	<1M	--	--	Do.
(D-36-4)16dbb-S1	Tenmile Spring	Harris Wash	5,320	10-14-67	Damp	--	--	Goode, 1969, table 1, no. 29.
(D-36-5)35aac-S1	--	do.	4,950	10-14-67	2-3E	--	--	Goode, 1969, table 1, no. 31. Seep from bedding planes.
(D-36-6)27bab-S1	--	do.	4,790	10-22-81	7.5M	10.0	140C	Discharge probably at Navajo Sandstone-Kayenta Formation contact.
(D-38-6)21ddd-S1	Cat Well	Dry Fork Coyote Gulch	4,840	--	1E	--	--	Potable. Reported by U. S. Gardner, U.S. Bureau of Land Management, June 18, 1976.

Number	Name of spring	Subdrainage	Altitude of land surface (ft)	Date inven-toried	Dis-charge (gal/min)	Tem-per-ature (°C)	Dis-solved solids (mg/L)	Remarks
(D-39-8)18ccd-S1	--	Hurricane Wash	4,190	10-21-81	--	--	--	Air reconnaissance. Water in alluvium. Probably perched by underlying Navajo Sandstone.
(D-39-9)34aaa-S1	--	Explorer Canyon	3,850	9-17-59	5-10E	--	--	Cooley, 1965, table 3, GJ-322. Air reconnaissance.
				6-16-81	5-10E	--	--	Multiple sources of discharge from the Navajo Sandstone.
34cbc-S1	--	do.	3,700	6-16-81	2-4E	--	--	Discharge from Navajo Sandstone.
(D-40-8)23bdb-S1	--	Willow Gulch	3,950	10- 7-81	--	--	--	Water in alluvium. Probably perched by underlying Navajo Sandstone.
(D-40-9)32bac-S1	--	Davis Gulch	3,400	9-17-59	50E	--	--	Cooley, 1965, table 3, GJ-316. Air reconnaissance. Head of perennial flow. Inundated by Lake Powell.
34acc-S1	--	Clear Creek	3,525	9-17-59	25-50E	--	--	Cooley, 1965, table 3, GJ-315. Air reconnaissance. Head of perennial flow. Inundated by Lake Powell.
35adc-S1	--	Indian Creek	3,550	9-17-59	25-50E	--	--	Cooley, 1965, table 3, GJ-314. Air reconnaissance. Head of perennial flow. Discharges from joint. Inundated by Lake Powell.
R(D-40-9) 1adb-S1	--	Long Canyon	3,650	9-17-59	50E	--	--	Cooley, 1965, table 3, GJ-340. Air reconnaissance. Inundated by Lake Powell.
(D-41-9) 3acc-S1	--	Glen Canyon	3,500	4-22-58	10-15M	--	--	Cooley, 1965, table 3, GJ-103. At Hole in the Rock. Discharges from bedding planes and faults. Inundated by Lake Powell.
8cdc-S1	--	Llewellyn Gulch	3,740	9-17-59	10E	--	--	Cooley, 1965, table 3, GJ-298. Head of flow in Llewellyn Gulch.
				6-16-81	--	--	--	No spring found. Flow begins about 2 miles upstream from lake shore (when lake elevation is 3,677 ft), and steadily gains flow in downstream direction. Flow is about 30 gal/min 0.5 mile upstream from lake. Several seeps in canyon.
21aab-S1	--	Glen Canyon	3,800	8-13-58	5E	--	--	Cooley, 1965, table 3, GJ-210. Discharges from bedding planes in Navajo Sandstone.
				6-17-81	5E	--	--	Discharges from contact between cross-bed sets. Less than 1 gal/min discharges into lake. Remainder supports plant life at discharge site or evaporates from bedrock surface.
30aaa-S1	--	Tributary to Cottonwood Gulch	3,700	9-17-59	10E	--	--	Cooley, 1965, table 3, GJ-296. Discharges from joint in Navajo Sandstone. Head of perennial flow.
				6-17-81	--	--	--	No spring found. Water begins flow out of alluvium about 0.5 mile upstream from lake shore, and steadily gains flow in downstream direction.
(D-42-7)36dad-S1	--	Dangling Rope Canyon	3,360	8-14-58	15E	--	--	Cooley, 1965, table 3, GJ-219. Combination spring, discharges from large joints. Inundated by Lake Powell.
(D-42-8)26cdd-S1	--	Glen Canyon (small side canyon)	3,920	8-13-58	5-10E	--	--	Cooley, 1965, table 3, GJ-215. Discharges from joints and bedding planes.
				6-17-81	5-10E	--	--	Discharges from contact between cross-bed sets high on canyon wall, about 150 feet above lake level.
R(D-42-8)25dba-S1	--	Navajo Valley	3,300	4-24-58	15M	--	--	Cooley, 1965, table 3, GJ-105. Bed of wash in amphitheater. Inundated by Lake Powell.
(D-43-5)13cdc-S1	--	Padre Creek	3,280	9- 1-58	200M	--	--	Cooley, 1965, table 3, GJ-248. Combination spring at head of small canyon. Inundated by Lake Powell.
24daa-S1	--	Glen Canyon	3,280	9- 1-58	80M	--	--	Cooley, 1965, table 3, GJ-249. Discharges from joints and bedding planes. Inundated by Lake Powell.
35daa-S1	--	Gunsight Canyon	3,280	9- 1-58	15M	--	--	Cooley, 1965, table 3, GJ-250. Discharges from large joint in bottom of canyon. Inundated by Lake Powell.
(A-41-9) 8ada-S1 (Arizona)	--	Glen Canyon	3,170	9- 1-58	25E	--	--	Cooley, 1965, table 3, GJ-244. Discharges from bedding planes on side of cliff. Inundated by Lake Powell.

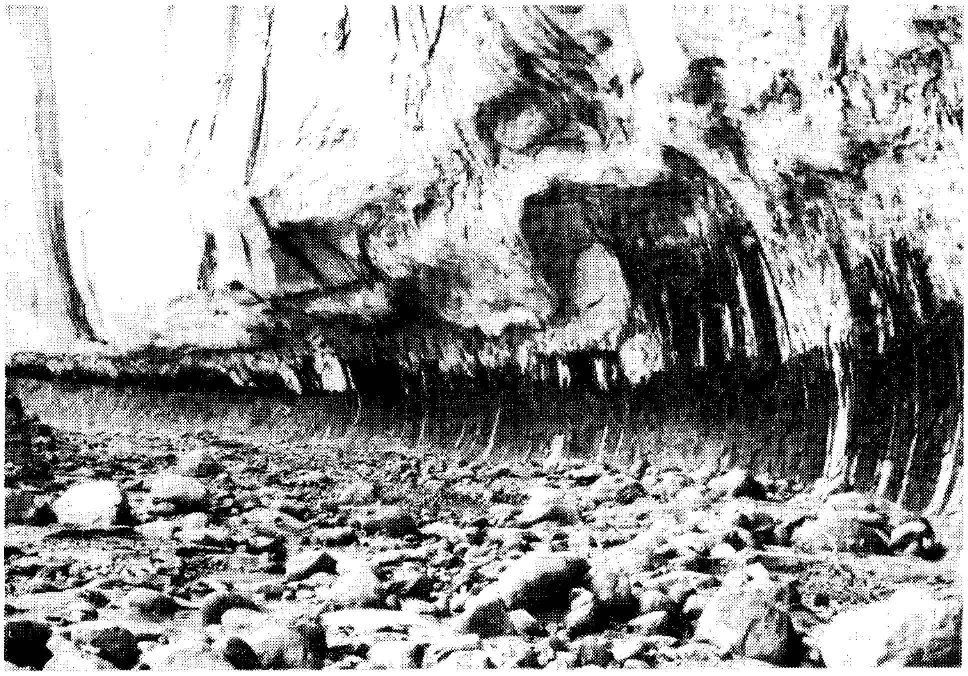

Figure 6.—Seep from the Navajo Sandstone in wall of canyon of Fiftymile Creek at location (D-40-8)24. Seepage occurs near top of dark staining on canyon wall, about 6 feet above bed of creek.

Spring (D-39-9)34aaa-S1 is in Explorer Canyon and may discharge from the main zone of saturation in the Navajo Sandstone. A second spring in Explorer Canyon, (D-39-9)34cbc-S1, not previously reported but inventoried during this study, also appears to discharge from the main zone of saturation in the Navajo. Discharge of (D-39-9)34aaa-S1 was 5 to 10 gallons per minute, about the same as Cooley's estimate (1965, table 3), and discharge of (D-39-9)34cbc-S1 was about 5 gallons per minute.

Spring (D-40-9)19bba-S1 was observed by Cooley (1965, table 3) from an aircraft, and he estimated the spring to have a discharge of 50 gallons per minute. The location coordinates given for the spring place it in the canyon of Fiftymile Creek, but the general location is stated by Cooley as Davis Gulch, which is several miles south of the canyon of Fiftymile Creek. Cooley's description of the spring source (a fault or large joint) indicates that the site is in the canyon of Fiftymile Creek, but no discharge was found when the site was inventoried during this study. The fault or large joint has caused a small side canyon to be formed but no water flowed from the canyon during the inventory.

Of the 40 springs discharging from formations in the Glen Canyon Group that have been inundated by Lake Powell, 17 had discharges estimated to be more than 5 gallons per minute, and 11 had discharges estimated to be more than 10 gallons per minute. The springs with discharges of more than 10 gallons per minute are shown on plate 1 and listed in table 9. The maximum estimated discharge was 200 gallons per minute from (D-43-5)13cdc-S1. Although investigation of the 11 springs with discharges of more than 10 gallons per minute is impossible, their locations indicate that the discharge is from the main zone of saturation. Eight are located within a mile of the original Colorado River channel and three are located in side canyons of the Escalante River basin near the river's original mouth. The total estimated discharge from the 11 springs was between 510 and 565 gallons per minute, or between 823 and 911 acre-feet per year, assuming constant discharge.

In addition to discharge from specific springs, Cooley (U.S. Geological Survey, written commun., 1982) estimated the streamflow of tributaries of the Colorado River in Glen Canyon. The tributaries and their estimated streamflows are listed in table 10. The streamflows represent ground-water seepage from all the formations into which the tributary canyons are cut and, therefore, are maximum values for discharge from the Navajo Sandstone. In addition, some of the estimates were made in April and May and may include streamflow from snowmelt or in response to precipitation, and some were made in August and may not include all of the ground-water seepage because of losses to evapotranspiration. The total streamflow estimated from the tributaries was between 5.3 and 8.2 cubic feet per second, or between 3,800 and 5,900 acre-feet per year, assuming constant flow.

As noted in the surface-water section of this report, the Navajo Sandstone also discharges water to some reaches of the Paria River. The minimum discharge was determined to be about 2.8 cubic feet per second, or 2,000 acre-feet per year, from streamflow measurements made on October 23, 1982 (table 6). The maximum discharge was determined to be 11.6 cubic feet per second, or 8,400 acre-feet per year, as determined from the average of three streamflow measurements made on April 22 and August 25, 1981, and March 3, 1982. The smaller value is only for the reach where the floor of Paria Canyon is in the Navajo Sandstone. The larger value includes interaction of the stream with the Carmel Formation on the upper end of the reach from U.S. Highway 89 to Lees Ferry, and interaction with the Kayenta, Moenave, and Chinle Formations on the lower end of the reach. The majority of the discharge probably is from the Navajo, Kayenta, and Moenave. Upward leakage from the Moenave to the Kayenta and from the Kayenta to the Navajo occurs near the southwestern margin of the Paria Plateau (see Recharge section). Downward leakage from the Navajo into the underlying Kayenta and Moenave probably occurs prior to discharge into the canyon cut by the Paria River in the northeastern part of the Paria Plateau, and part of the water discharged by the Kayenta and Moenave probably has been discharged previously by the Navajo. The 8,400 acre-feet per year thus represents a maximum value for both direct and indirect discharge from the Navajo to the Paria River.

Five springs discharge from the Navajo Sandstone along a 2.5-mile section of the East Kaibab monocline (pl. 1), including Pump Canyon and Cottonwood Springs, (C-40-1)11ddb-S1 and (C-40-1)23bba-S1 (table 9), but the springs are not discharging from the main zone of saturation in the Navajo. Rather they are discharging from a perched zone in the Navajo, caused by intertonguing between the Navajo and the less permeable Carmel Formation. Several springs have been reported in the Boulder-Escalante area by residents and by Goode (1969, p. 15), particularly in the Mamie Creek and Calf Creek drainages. These springs are in areas of recharge to the Navajo and probably represent rejected recharge from the main zone of saturation in the Navajo.

Table 10.--Seepage to tributaries of the Colorado River in Glen Canyon from the Navajo Sandstone, Kayenta Formation, and Wingate Sandstone
[Abbreviation used in column headings: gal/min, gallons per minute.]

Discharge from individual springs: e, estimated.

Tributary	Date measured	Gross discharge in stream channel (gal/min)	Date measured	Discharge from individual springs (gal/min)	Net discharge by seepage (gal/min)
Long Canyon	8-12-58	[1]50	9-17-59	50	0
Llewellyn Gulch	8-12-58	[1]25	9-17-59	10	15
Hidden Passage	4-23-58	[2]25	9-17-59	<10	15-25
Driftwood Canyon	8-13-58	15	8-13-58	5-10	5-10
Dangling Rope Canyon	8-14-58	10	8-14-58	20e	0
Rock Creek	4-22-58	75	4-25-58	25-35	40-50
Last Chance Creek	8-14-58	[3]200	--	--	0-200
Kane Creek	8-15-58	50-100	9- 1-58	10	40-90
Padre Canyon	10- 1-58	200	9- 1-58	200	0
0.5 mile downstream from Padre Canyon	10- 1-58	80	9- 1-58	80	0
Gunsight Canyon	9- 1-58	15	9- 1-58	15	0
Warm Creek	9- 1-58	300	9-18-59, 12- -59	5-15	285-295
Wahweap Creek	4-26-58	2,000-3,000	--	0	2,000-3,000

[1] Discharge from Wingate Sandstone.
[2] Discharge from Kayenta Formation.
[3] Discharge reported to be summer runoff--water reported to be muddy.

Based on the foregoing discussion, total annual discharge of springs and seepage from the regional ground-water system (main zone of saturation) in the Navajo Sandstone is estimated to be between 6,600 and 15,200 acre-feet. Included in this value is the 823 to 911 acre-feet from inundated springs, the 3,800 to 5,900 acre-feet from tributary discharge in drainages other than the Paria River, and the 2,000 to 8,400 acre-feet from discharge in the Paria River drainage. The assumptions that discharge from inundated springs is continuing at pre-inundation rates, and that all flow in tributary canyons is ground-water discharge from the Navajo and has not been affected by evapotranspiration, runoff, or ground-water discharge from other formations, contribute to possible inaccuracy of the estimate; nevertheless, the estimate gives an order-of-magnitude estimate of discharge from springs and seepage.

The quantity of discharge from wells completed in the Navajo Sandstone in the Kaiparowits Plateau area is estimated to be about 1,500 acre-feet per year. In recent years, about 300 acre-feet per year have been withdrawn in the Wahweap Bay area to supply water to the Glen Canyon National Recreation Area. Three other wells supply water from the Navajo Sandstone for domestic use in the Wahweap Bay area: two wells supply water to small groups of mobile homes, and the third well supplies water to a motel. Total annual discharge from these three wells is estimated to be no more than 100 acre-feet.

Three wells in the Paria River-U.S. Highway 89 area supply water from the Navajo Sandstone for domestic use. Two wells supply small groups of residences and the third supplies the visitors' center at the Paria Canyon Primitive Area. Total annual discharge from these three wells is estimated to be no more than 30 acre-feet.

Four irrigation wells and five domestic wells withdraw water from the Navajo Sandstone in the Boulder area. About 300 acres, nearly all of which are in alfalfa, are irrigated with water from the Navajo. The U.S. Soil Conservation Service (Verl Matthews, oral commun., May 1982) has estimated annual consumptive use in the Boulder area for alfalfa to be 25.96 inches, which indicates a total maximum discharge from the irrigation wells of approximately 650 acre-feet annually at 100-percent irrigation efficiency. The estimated efficiency of the sprinkler systems in use is 65 to 70 percent. The 65-percent value gives a total annual water requirement of 1,000 acre-feet. Annual discharge from the five domestic wells in the Boulder area is estimated at 5 acre-feet.

Evapotranspiration in the Kaiparowits Plateau area is difficult to estimate, but probably is small. The Utah Division of Water Resources (1976, p. 47-55) has estimated annual wetland consumptive use in the Escalante River basin to be 1,440 acre-feet. The definition of consumptive use by the Utah Division of Water Resources (1976, p. 41) is similar to the definition of evapotranspiration by Langbein and Iseri (1960, p. 9).

In the estimate by the Utah Division of Water Resources, the Escalante River basin is subdivided into three subbasins (fig. 7). Of the 1,440 acre-feet of wetland consumptive use in the Escalante River basin, 720 acre-feet are estimated to be consumed in subbasin 1 and 680 acre-feet are estimated to be consumed in subbasin 2. The Navajo Sandstone is at or near the surface in only a small part of these subbasins. Outcrop of Navajo Sandstone in subbasin 1 comprises less than 10 percent of the subbasin area; therefore,

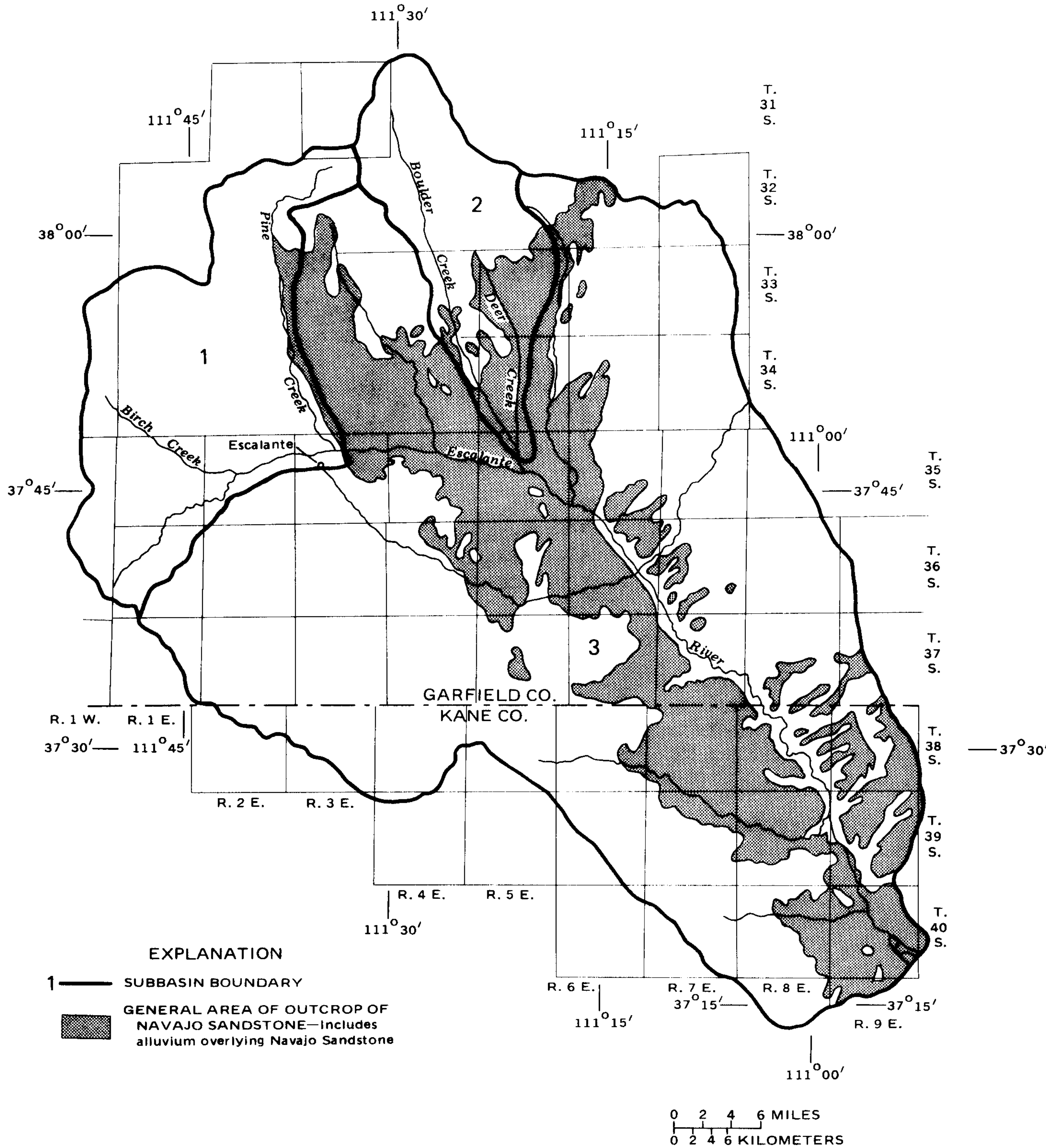

Figure 7.—Subdivisions of the Escalante River basin used in wetland consumptive-use determination (from Utah Division of Natural Resources, 1976, p. 31).

evapotranspiration from the Navajo Sandstone in subbasin 1 is estimated to be negligible. The Navajo is at or near the surface in about one-third of subbasin 2; however, most of the area is uplands and the depth to ground water is generally below the depth of potential evapotranspiration. For example, the depth to water in six wells in the Boulder area ranges from 80 to 445.6 feet. Evapotranspiration from the Navajo in subbasin 2 is estimated to be about the same as in subbasin 3. Wetland consumptive use in subbasin 3 is estimated to be 40 acre-feet per year, much of which probably is from the Navajo. Based on the above limited observations, evapotranspiration from the Navajo Sandstone in the Escalante River basin is estimated to be about 100 acre-feet per year.

The Paria River basin contains several stream reaches where the Navajo Sandstone is at or near the surface and could be affected by evapotranspiration: notably in Kaibab Gulch, along Hackberry Creek, and along the Paria River mainstem, both in Paria Canyon and in a reach about 10 miles south of Cannonville (pl. 2). The conditions in these areas are similar to those in subbasin 3 of the Escalante River basin. The canyons are steep and narrow and phreatophytes are few in number. The amount of evapotranspiration from the Navajo Sandstone in the Paria River basin, therefore, is estimated to be about the same as that in the Escalante River basin, about 100 acre-feet per year.

In the Wahweap Creek basin probably no significant evapotranspiration from the Navajo Sandstone occurs. Glen Canyon is the only location where any Navajo Sandstone is exposed, and inundation of the canyon has precluded evapotranspiration there.

In summary, the amount of evapotranspiration from the Navajo Sandstone is small because areas where the saturated Navajo is at or near the land surface (in reach of phreatophytes) generally are limited to deep, narrow canyons. Even in those areas, phreatophytes apparently exist chiefly on perched water in stream-valley alluvium. The estimated annual discharge from the Navajo Sandstone by evapotranspiration is only about 200 acre-feet.

Some water probably discharges from the Navajo Sandstone by upward leakage to the Carmel Formation. This condition apparently exists in the northern Paria Plateau area where water is confined in the Navajo and the hydraulic gradient is upward from the Navajo to the Carmel. The condition probably also exists beneath the Kaiparowits Plateau where the Navajo is assumed to be fully saturated. The amount of water discharging from the Navajo Sandstone by upward leakage is unknown.

Downward leakage from the Navajo Sandstone into the underlying Kayenta and Moenave Formations apparently takes place in the southern part of the Paria Plateau area near the margin of the plateau. Saturated thickness of the Navajo Sandstone in the area is very small. At four wells, (A-39-4)6cbb-1, (A-40-4)19bab-1, (A-40-5)5ccc-1, and (A-40-6)3ccc-1, the Navajo is completely unsaturated, and the water table is in the underlying Kayenta and Moenave Formations. Direction of ground-water movement in the area is to the northeast, away from the area of unsaturated Navajo (fig. 5). South of the Paria Plateau, the Navajo, Kayenta, and Moenave are absent. The only probable source of ground water in the Kayenta and Moenave Formations is precipitation on the Paria Plateau, which infiltrates into and moves downward through the Navajo and into the underlying Kayenta and Moenave.

Whether downward leakage occurs in other areas is unknown. Certainly, downward movement is impeded by the underlying Kayenta Formation, as is evidenced by springs and seeps at the Navajo-Kayenta contact at several locations in the canyons of the Escalante River basin. Examples are spring (D-36-6)27bab-S1 (table 9) in Harris Wash and seeps along the canyon wall of the Escalante River at general location (D-36-6). The amount of water discharging from the Navajo Sandstone by downward leakage is unknown.

In summary, estimated values for discharge from the Navajo Sandstone can be made only for springs and seepage, wells, and evapotranspiration. Upward and downward leakage cannot be quantified with the data available. The total quantifiable discharge from the main zone of saturation in the Navajo Sandstone is estimated to be between 8,300 and 16,900 acre-feet: 6,600 to 15,200 acre-feet from springs and seepage, 1,500 acre-feet from wells, and 200 acre-feet by evapotranspiration.

Storage

The amount of water recoverable from storage in the Navajo Sandstone in the Kaiparowits Plateau area can only be roughly estimated because data regarding the saturated thickness of the Navajo are very limited. In order to estimate the volume of water recoverable from the Navajo, the following data were used: the specific yield of the formation, total thickness of the formation, the altitude of the top of the formation, and the altitude of the surface of the saturated zone. Where the Navajo is completely saturated, the saturated thickness is equal to the total thickness. Where the Navajo is not completely saturated, the saturated thickness has been estimated by subtracting the altitude of the surface of the saturated zone from the altitude of the top of the formation, and subtracting that difference from the total thickness of the formation. Known altitudes of the top of the Navajo are shown in figure 8 and known thicknesses of both the Navajo and the entire Glen Canyon Group are shown in figure 9. Areas where the Navajo is completely saturated are shown in figure 5.

The values stated for water recoverable from storage in the Navajo Sandstone are the amounts that could be theoretically recovered if the Navajo could be completely drained. The actual amounts of water recoverable from the Navajo are less than the amounts stated because of various physical limitations, including well spacing and well yields; and various economic, legal, and environmental constraints.

Meinzer (1923, p. 28) defines specific yield as the ratio of (1) the volume of water that, after being saturated, a rock or soil will yield to gravity to (2) its own volume. Hood and Danielson (1981, p. 36) have estimated the specific yield of the Navajo Sandstone in the lower Dirty Devil River basin to be 9 percent. In this report, an estimated specific yield of 10 percent has been used to allow for the slightly larger total porosity values in the area compared to those in the lower Dirty Devil River basin (table 7).

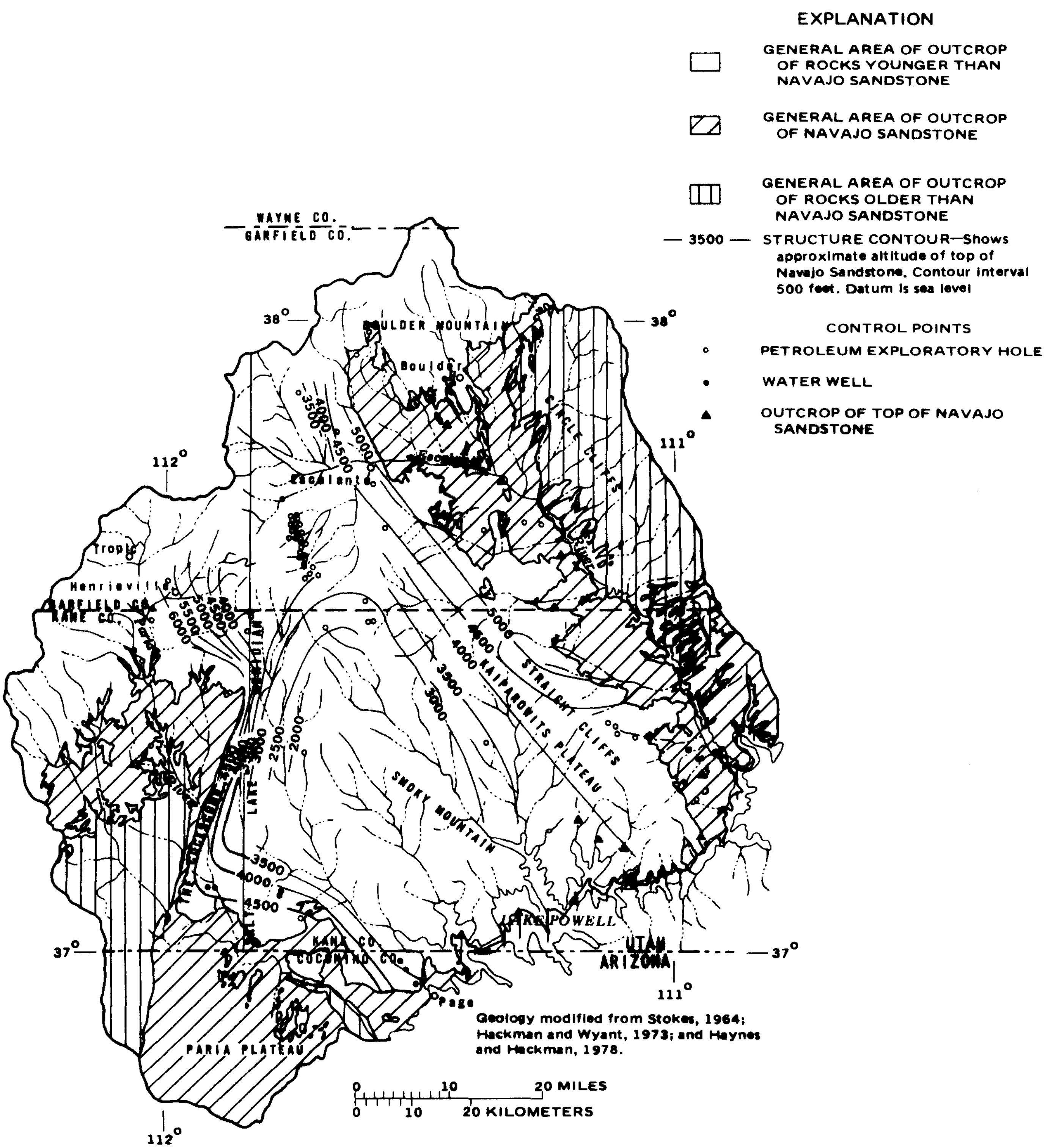

Figure 8.—Approximate altitude of the top of the Navajo Sandstone.

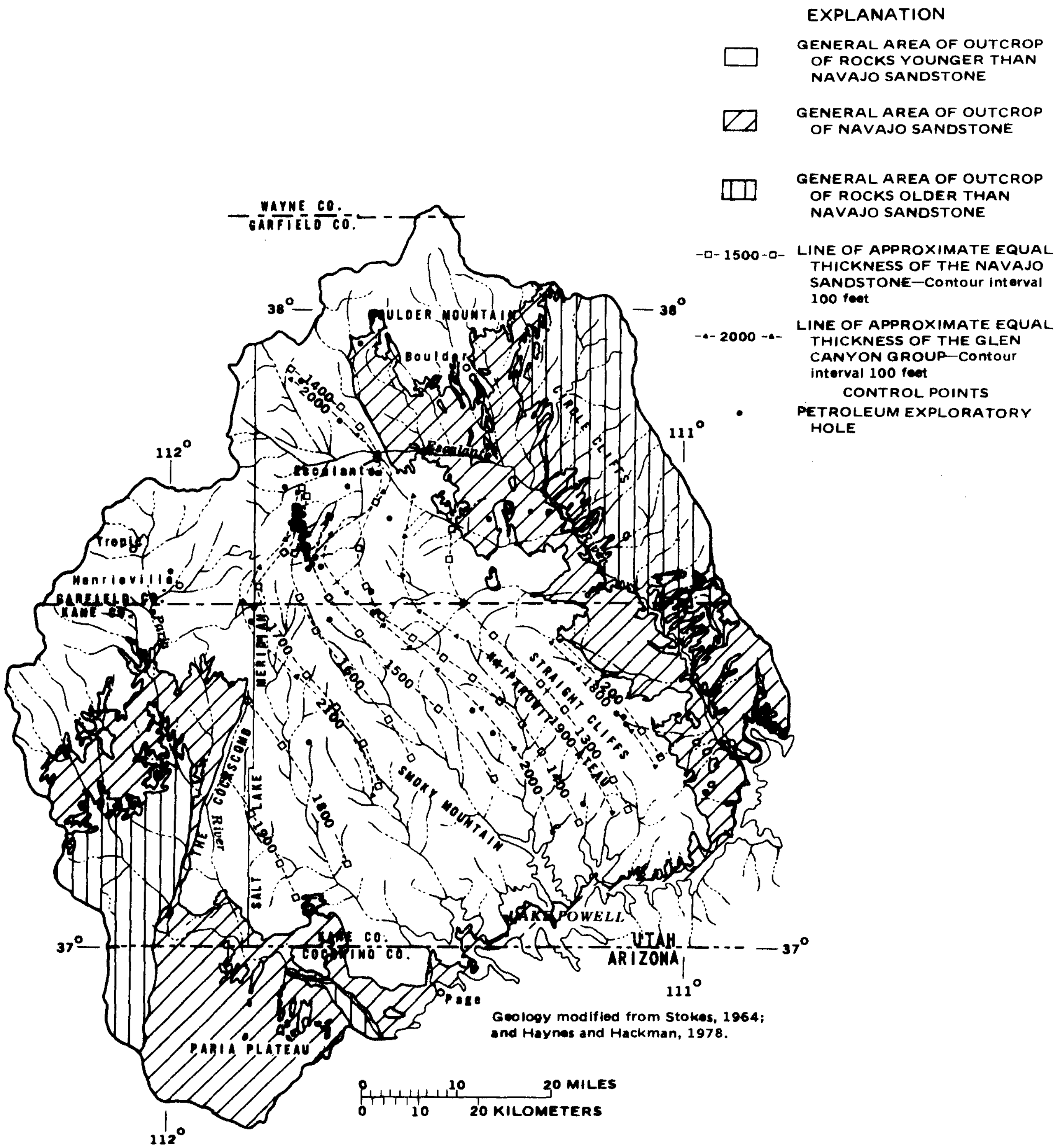

Figure 9.—Approximate thickness of the Navajo Sandstone and the Glen Canyon Group, undivided.

The area where the Navajo Sandstone is completely saturated is about 1,400 square miles and the average thickness is estimated to be 1,600 feet. The amount of water recoverable in the area is estimated to be about 140 million acre-feet.

North and west of the area of complete saturation, very little information about water in the Navajo Sandstone is available. It varies from nearly 100 percent saturated bordering the zone of complete saturation to totally unsaturated, as at well (D-35-4)20cca-1. Because of the lack of information, an average of 50 percent saturation has been assumed. The area is approximately 750 square miles and the average estimated saturated thickness is 1,000 feet. The amount of water estimated to be recoverable from storage in this area is about 50 million acre-feet. The total amount of water recoverable from the Navajo Sandstone in the entire Kaiparowits Plateau area is estimated to be about 190 million acre-feet.

The few available water-level records for the Kaiparowits Plateau area (fig. 10; and table 13, at back of report) are insufficient to indicate significant long-term changes in storage except in the Lake Powell area. The ground-water system in most of the Kaiparowits Plateau area is assumed to be in a state of equilibrium whereby ground-water recharge and discharge are virtually equal over the long term. Considering the small amount of withdrawal by wells in the area, it is unlikely that there has been any major long-term decrease in storage. The variations in water levels given in figure 10 and table 13 primarily are caused by seasonal variations in recharge and discharge, including withdrawals. There has been a significant increase in storage adjacent to Lake Powell because of the lake's effect on ground water in the area (see section on Effects of Lake Powell).

Chemical Quality

Dissolved-solids concentrations were measured for 27 water samples collected from the Navajo Sandstone (table 14, at back of report) and were estimated for 10 additional samples for which only specific conductance of the water was measured. The estimates are based on a dissolved solids to specific conductance ratio of 0.63 to 1 for the 27 analyzed samples. Based on the determined and estimated dissolved-solids concentrations, water in the Navajo ranges from fresh to slightly saline. It is fresh in the principal recharge areas (near Boulder Mountain, the Paria Plateau, and west of the Kaiparowits Plateau). In these areas, the Navajo is either at the surface or overlain by alluvium or dune sand. The water is slightly saline in the area of complete saturation near the Paria River where it is crossed by U.S. Highway 89, and in the Wahweap Bay area near Lake Powell. In both of these areas, the Carmel Formation overlies the Navajo and is generally at the land surface.

Information regarding the quality of water in the Navajo Sandstone underneath the Kaiparowits Plateau is scarce, and what is available from records of oil-test holes is qualitative. The water probably is saline, and the degree of salinity probably varies with location.

In this report, ground water has been classified chemically using the system of Davis and DeWiest (1966, p. 119). In their system, only ions present in concentrations that represent more than 20 percent of the total milliequivalents per liter of cations or anions are used to name the water

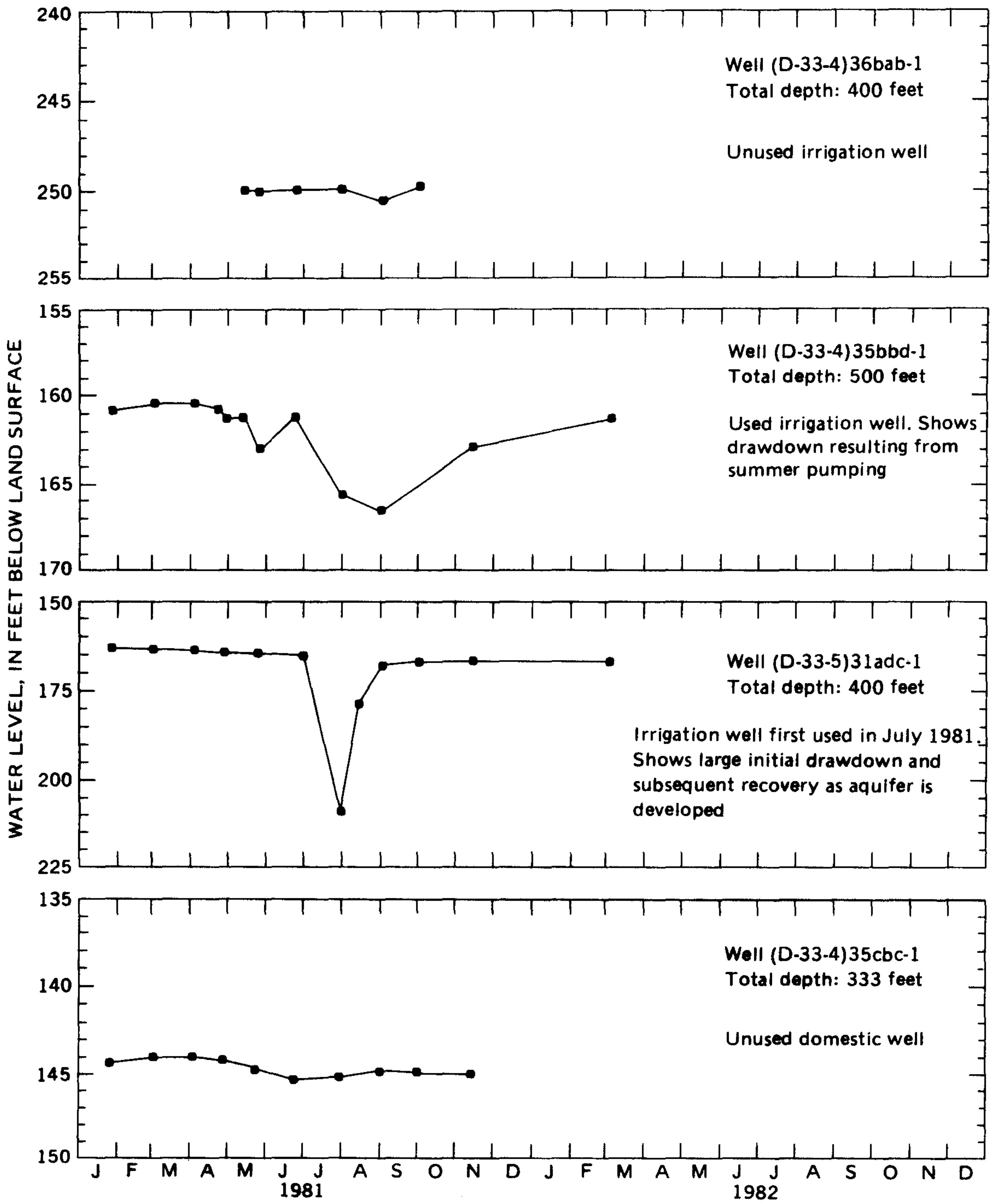

Figure 10.—Water levels in selected observation wells completed in the Navajo Sandstone.

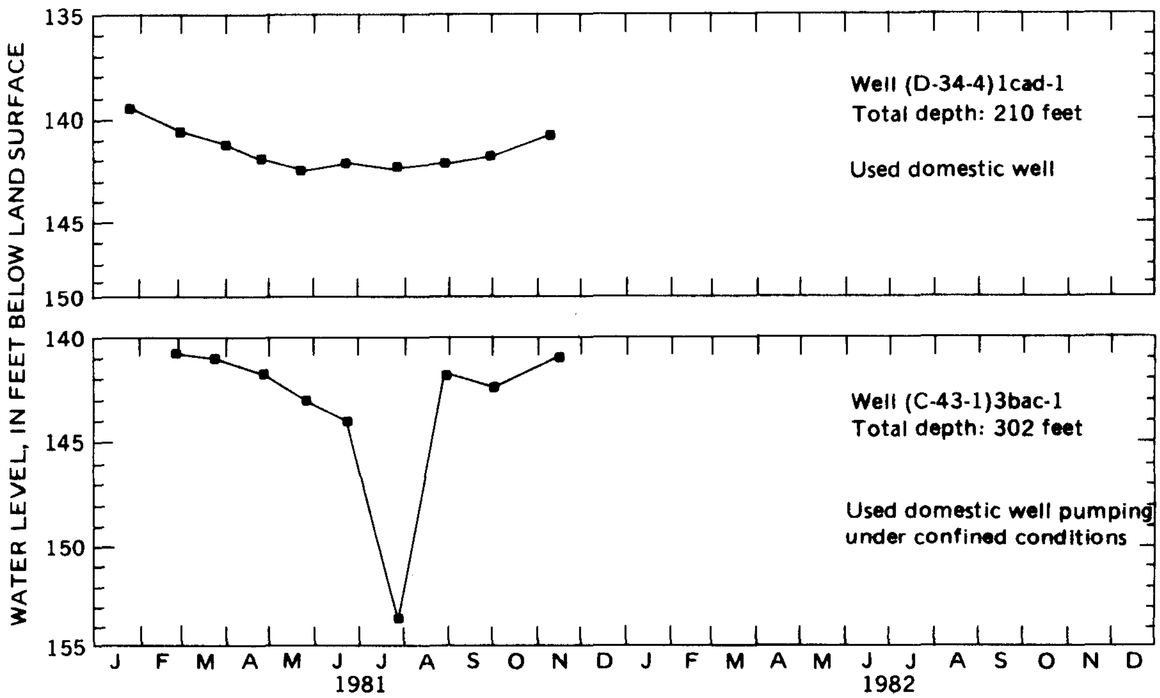

Figure 10.—Water levels in selected observation wells completed in the Navajo Sandstone—Continued.

type, and an ion present at levels greater than 60 percent of the total milliequivalents of cations or anions is used alone to name the water type. In mixed water types, ions present in amounts greater than 20 but less than 60 percent of the total cations or anions present are listed in descending order of concentration. For example, the sample collected from well (A-41-8)4dda-1 on August 31, 1981 had a cation composition of 40 percent sodium, 31 percent calcium, 26 percent magnesium, and 3 percent potassium; and an anion composition of 44 percent sulfate, 37 percent bicarbonate, and 19 percent chloride. This water is classified as sodium calcium magnesium sulfate bicarbonate. In most cases there are fewer ions with percentages greater than 20 percent of the total cations or anions present and the description of the water type is much simpler.

The chemical type of water in the Navajo Sandstone varies considerably depending chiefly on dissolved-solids concentration. In the areas of recharge and where the Navajo is at the surface (near Boulder Mountain, the Paria Plateau, and west of the Kaiparowits Plateau), the water type is calcium magnesium bicarbonate. In the area near the Paria River and U.S. Highway 89, the water type is sodium calcium sulfate. In the Wahweap Bay area, the water type generally is sodium calcium sulfate bicarbonate. Concentrations of major constituents in water samples collected at selected sites are given in Table 14.

Water temperature in the Navajo Sandstone varies with distance from recharge areas. In the recharge areas, average temperature of five samples in the Boulder area was 13.1 °C, and the average temperature of three samples in the Paria Plateau area was 13.3 °C. Near the area of discharge, in the Wahweap Bay area, the average temperature of 13 samples collected from eight wells was 22.2 °C. The water temperatures measured during collection of samples for chemical analyses (table 14) ranged from 11.5 °C at well (D-33-4)35bbd-1 to 24 °C at wells (A-41-8)4dda-1, (A-42-8)35dab-2, and (A-42-8)35dcd-1.

Effects of Lake Powell

Lake Powell, formed in Glen Canyon by impoundment of the Colorado River behind Glen Canyon Dam, has had a significant effect on ground water in part of the Kaiparowits Plateau area. Prior to formation of Lake Powell, there was a natural ground-water gradient toward the Colorado River, the channel of which is at an altitude of 3,142 feet at Glen Canyon Dam. The filling of Lake Powell began in the fall of 1962 and by June 1980, its surface altitude was 3,700.5 feet, or 558.5 feet higher than the channel of the Colorado River at Glen Canyon Dam (fig. 11; and table 15, at back of report). That increase has caused the ground-water system to be out of equilibrium near the lake, with the following effects: (1) significant rises of water levels in wells near the lake shore, (2) a reversal of the ground-water gradient near Lake Powell, (3) local changes from unconfined to confined conditions in the Navajo Sandstone, and (4) local changes in the quality of ground water near Lake Powell. The relation of ground-water levels in three wells to the changing surface altitude of Lake Powell is shown in figure 11 and tables 13 and 15.

The largest observed water level rise during filling of Lake Powell was 357 feet in well (A-41-8)4dda-1 (table 13). The water levels in wells (A-41-8)23dac-1 and (A-42-8)36cbc-1 near the lake have risen, respectively, 343 and 348 feet, and the water level in well (D-43-2)14bab-1, about 4 miles from the lake, has risen 28 feet (fig. 11 and table 13). The water levels in wells (D-43-1)2bda-1 and (D-43-1)2cab-1, which are about 11 miles from the lake, have risen about 10 feet (table 12). The water-level rises in wells (D-43-2)14bab-1, (D-43-1)2bda-1, and (D-43-1)2cab-1 are a result of the flattening of the ground-water gradient toward Lake Powell rather than a direct result of bank storage. The water levels in the wells are at significantly higher altitudes than the surface of the lake--as much as 350 feet at well (D-43-1)2cab-1.

The regional ground-water gradient is toward Glen Canyon and Lake Powell as is indicated by water levels in wells in Townships 43 and 44 South, Ranges 2 and 3 East (fig. 12). The water levels are at a higher altitude than the surface of Lake Powell, and ground-water movement is toward the lake. Near the shore of Lake Powell, however, ground-water levels measured in 1980, 1981, and 1982 in wells in Townships 41 and 42 North, Range 8 East, are at a lower altitude than the surface of Lake Powell, and indicate a ground-water gradient and ground-water movement away from the lake. For example, the ground-water level at well (A-42-8)32cdd-1, about 1.5 miles from Glen Canyon Dam, is about 88 feet lower than the surface of Lake Powell.

The local reversal of the gradient near the shore of Lake Powell is due to the inability of the Navajo Sandstone and other formations to readily accept water into bank storage as rapidly as the level of the lake has risen.

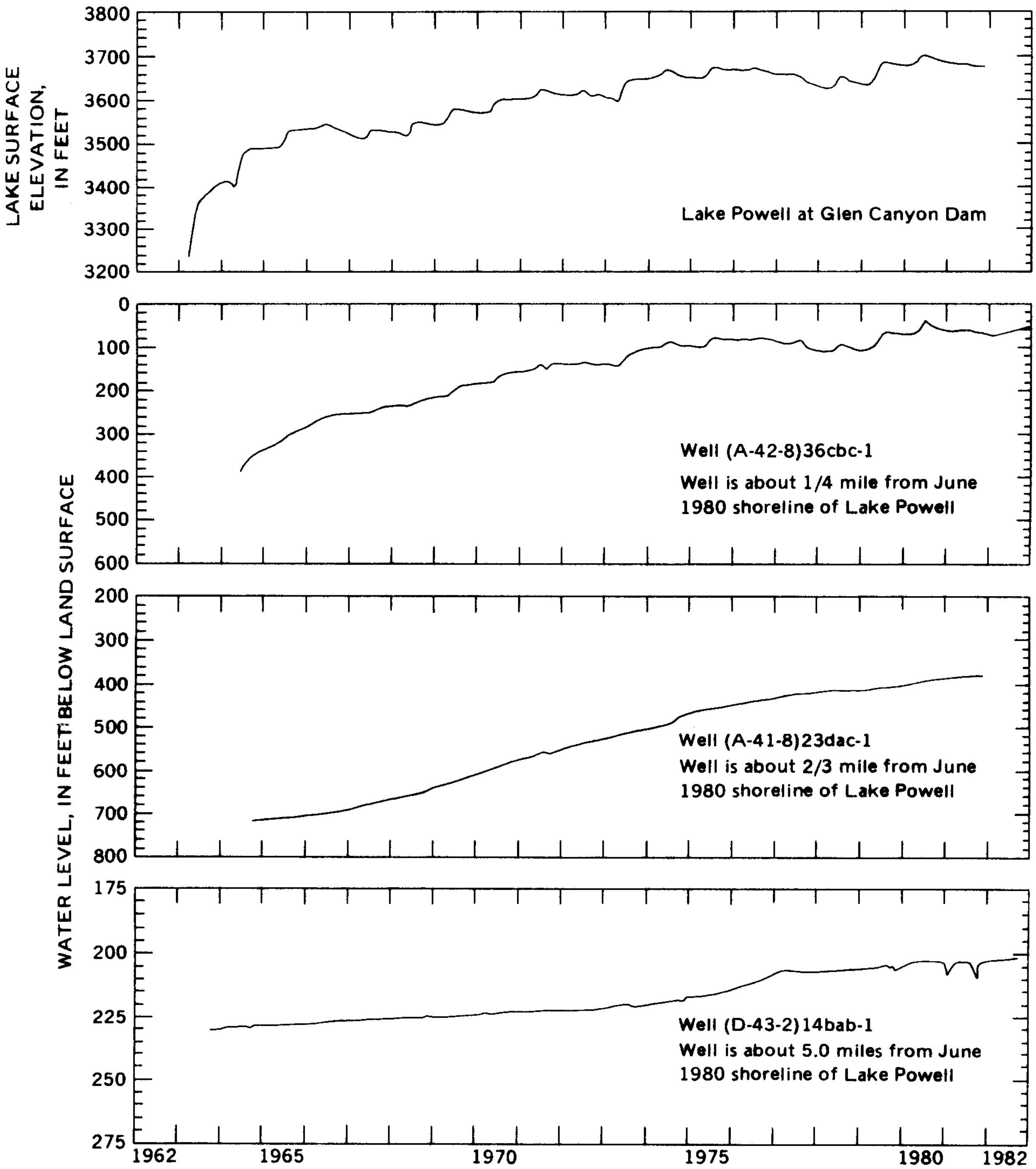

Figure 11.—Water levels of Lake Powell and in several nearby observation wells.

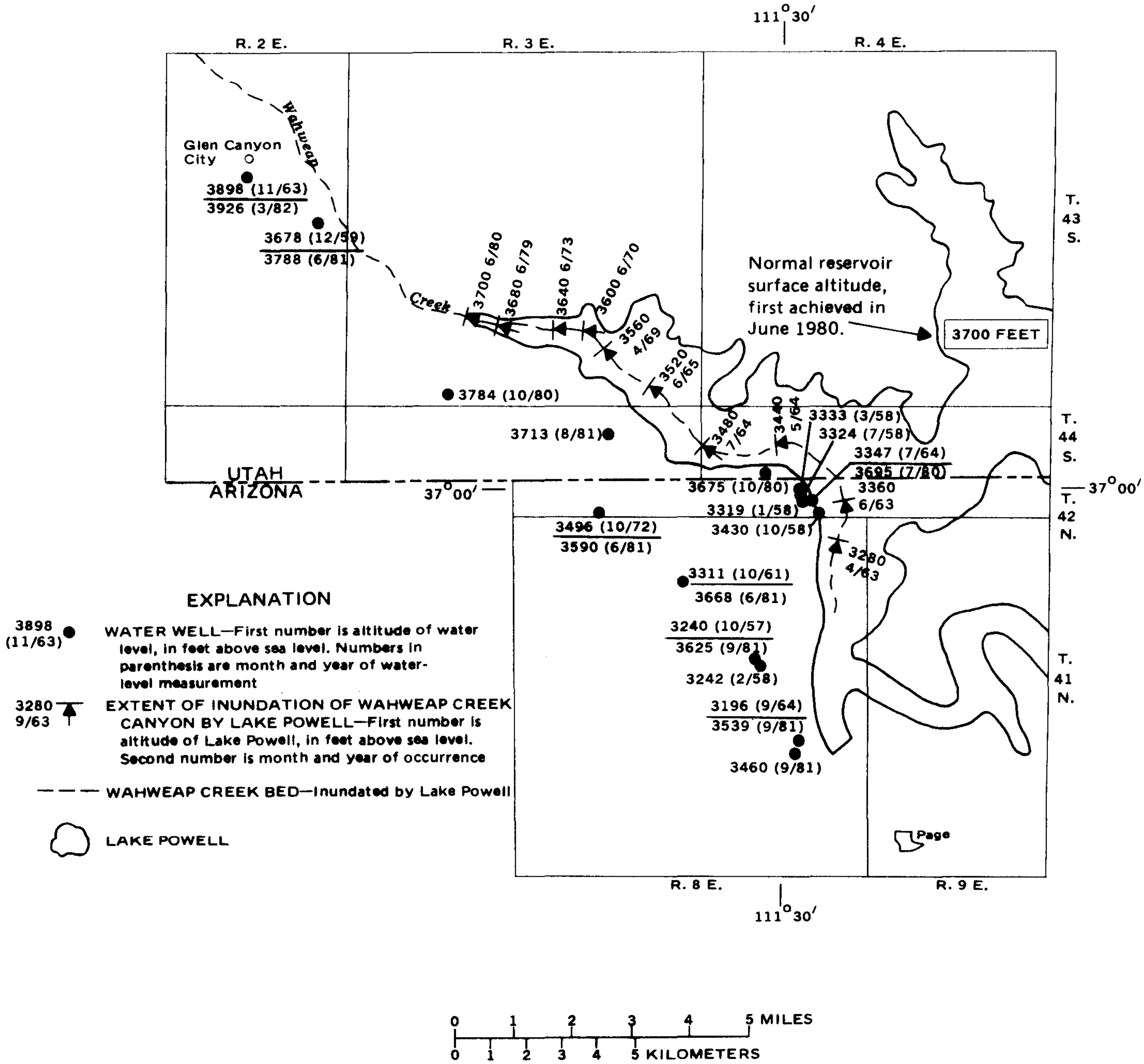

Figure 12.—Water levels of Lake Powell (1963-80) and in selected wells near Lake Powell at selected times.

The ground-water system near Lake Powell is not in equilibrium because of the rapid and large increase in hydraulic head at the lake. When equilibrium is re-established, the reversal of the ground-water gradient near the lake will be eliminated and a continuous gradient to the lake will exist. This gradient will be much flatter than the original gradient to the Colorado River, and water levels in the wells mentioned above (up to 11 miles from the lake) will continue to be above pre-lake levels.

With the filling of Lake Powell, the attendant rising ground-water level has caused formerly unsaturated Navajo Sandstone to become saturated to the base of the overlying less permeable Carmel Formation. This has created confined conditions where unconfined conditions formerly existed. Under confined conditions, ground-water levels respond rapidly to changes in recharge and discharge. Thus, water levels in nearby wells in the confined part of the Navajo, for example in well (A-42-8)36cbc-1, closely follow changes in water levels in Lake Powell (fig. 11). Conversely, the water level in well (A-41-8)23dac-1, which is completed in an unconfined part of the Navajo, reflects the gross increase in bank storage, but not the minor fluctuations in the water level of Lake Powell (fig. 11).

Available data indicate that Lake Powell has also caused local changes in the ground-water quality, chiefly by creating a more effective hydrologic connection between the Navajo Sandstone and the Carmel Formation. As noted earlier, the Carmel contains easily soluble minerals including gypsum. As Lake Powell filled, the top of the Navajo and the lower parts of the Carmel near the lake became saturated with water going into bank storage. This hydrologic connection between the formations allowed salts to be dissolved from the Carmel and transported to wells that obtain water from the Navajo, where the pumping of the wells created a cone of depression to an altitude below the Navajo-Carmel contact. Consequently, there has been an increase in dissolved-solids concentrations, chiefly sulfate, in water from several of those wells.

Major ion chemistry of water in wells in the Wahweap Bay area, and of water from Lake Powell and the Colorado River at Lees Ferry, is shown in figure 13. For each well or set of wells, there is an analysis of a water sample collected both prior to the beginning of filling of Lake Powell and in 1977 or 1981. The analyses from well (A-42-8)35dab-2 indicate a significant increase in dissolved-solids concentration, a three-fold increase in the concentration of sulfate, and a decrease in bicarbonate plus carbonate concentration. The well is in the area where the Navajo is confined by the Carmel Formation.

The analyses of samples from wells (A-42-8)36ccc-1 and (A-42-8)36ccc-2 indicate a 50 percent decrease in concentration of dissolved solids and major ions. The chemistry changed to more closely match that of Lake Powell. The wells are in an area where the ground-water level is below the Navajo Sandstone-Carmel Formation contact, and the water has not been affected by the Carmel, but has been affected by Lake Powell water entering the ground-water system.

The analyses from wells (A-41-8)14bca-1 and (A-41-8)14bcb-1 indicate that concentrations of dissolved solids and major ions have remained relatively constant. The wells are in an area where the ground-water level is below the

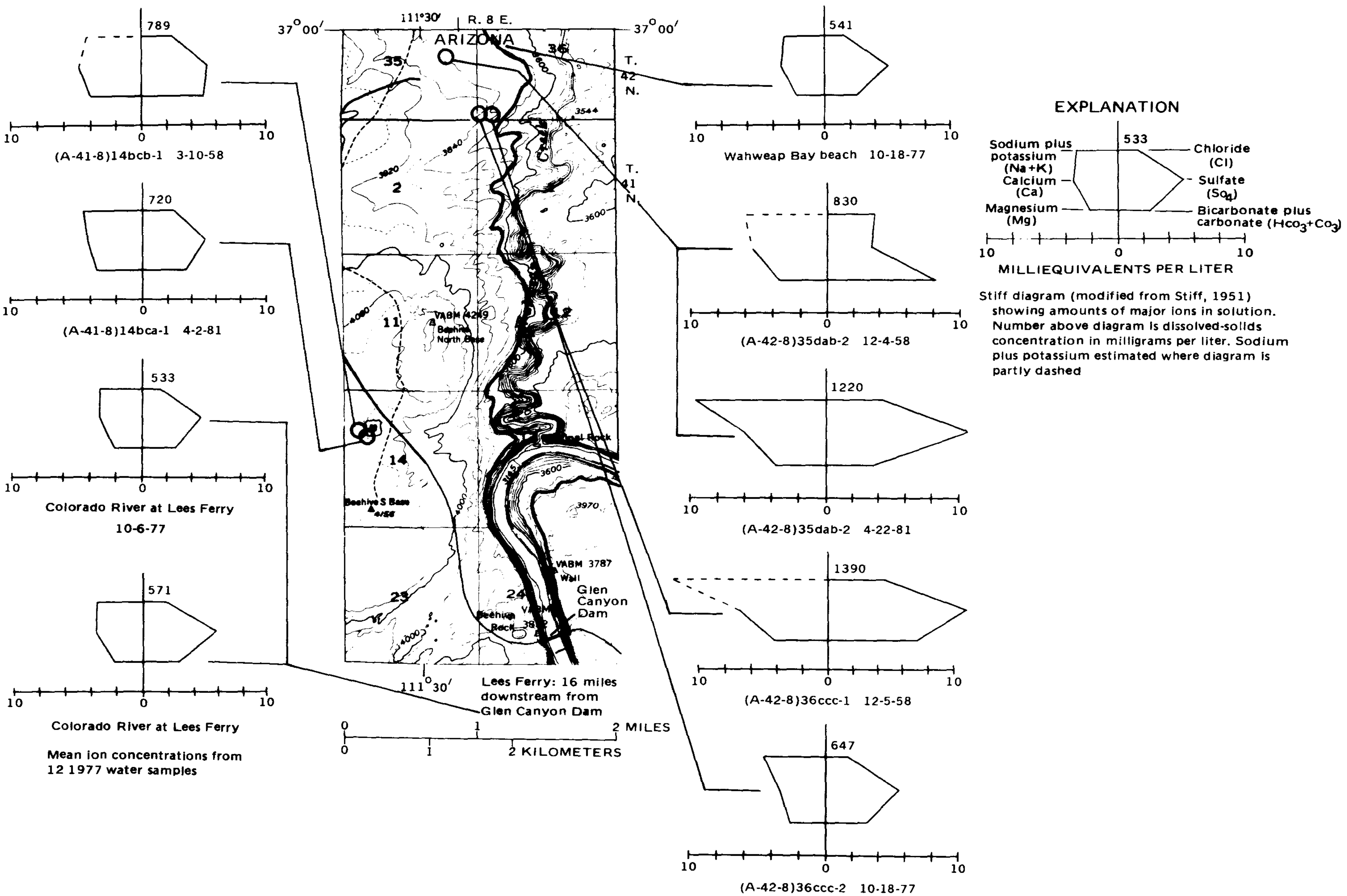

Figure 13.—Major ion chemistry of water in wells in the Wahweap Bay area, in Lake Powell, and in the Colorado River at Lees Ferry at selected times.

Navajo Sandstone-Carmel Formation contact, and are about 1 mile from Lake Powell. The water levels in the wells are lower than the level of Lake Powell and in the area affected by the reverse gradient. The water in the wells probably is affected by Lake Powell water; however, the major ion chemistry of the ground water prior to Lake Powell and that of Lake Powell water is similar and, therefore, the change in chemistry is small.

The analyses of samples from wells (A-41-8)23dac-1 and (A-41-8)23dcd-1 indicate that concentrations of dissolved solids and all major ions except chloride have decreased markedly. The two wells are located less than 1 mile from the present (1982) shoreline of the reservoir, and are along a line nearly parallel with Glen Canyon Dam. At the well sites, the Navajo Sandstone is unconfined and at the surface.

The concentrations of major ions have decreased to levels less than those in water of Lake Powell or in the Colorado River at Lees Ferry (table 14). Possibly a larger part of the ground-water flow through the area of the two wells is now moving from the eastern part of the Paria Plateau than prior to the presence of Lake Powell. Prior to the lake, ground-water movement was primarily from the northwest. Major ion concentrations in ground water in the eastern part of the Paria Plateau [for example at well (A-40-5)12ddb-1] are similar to those in 1981 water samples from wells (A-41-8)23dac-1 and (A-41-8)23dcd-1.

Three water-supply wells in the Glen Canyon National Recreation Area, (A-42-8)35dab-2, (A-42-8)35dcd-1, and (A-42-8)36ccc-2, have had concentrations of dissolved arsenic in excess of the U.S. Environmental Protection Agency (1976) drinking-water standard of 0.05 milligram per liter (table 16, at back of report). Arsenic concentration was not determined in water samples in the area prior to 1977 so it is not known if ground water contained significant concentrations of arsenic prior to inundation of Glen Canyon; however, at all three well sites ground-water levels have risen to a level higher than the Navajo Sandstone-Carmel Formation contact as a result of the filling of Glen Canyon by Lake Powell. Arsenic may be one of the materials being leached from the Carmel Formation.

Chemical analyses of surface water indicate that the arsenic found in the previously mentioned wells does not come from Lake Powell water entering the ground-water system. In the October 18, 1977 analysis of Wahweap Bay water, no arsenic analysis was made; however, dissolved arsenic analysis has been included intermittently in the Lees Ferry water analyses beginning in May 1974. The largest value recorded is 0.019 milligram per liter on May 28, 1974, and the next largest value is 0.006 milligram per liter on November 1, 1978. These values are much less than those found in ground water from the three wells.

Effects of Large-Scale Withdrawal

The withdrawal of large quantities of water from the Navajo Sandstone in the Kaiparowits Plateau area could cause one or more effects on the ground-water system. Among the possible effects are declines of water levels in existing wells, reduction of streamflows, and deterioration of water quality.

In order to determine both the degree of effects and the areal extent of influence of large-scale withdrawals from the Navajo, the effects of two hypothetical withdrawal plans have been investigated. The first plan considers withdrawal of 40,000 acre-feet per year from a well or group of wells (roughly the amount required by a large thermoelectric powerplant) from an aquifer having a transmissivity of 5,000 feet squared per day and a storage coefficient of 0.0045. The second plan considers withdrawal of 20,000 acre-feet per year from a well or group of wells from an aquifer having a transmissivity of 10,000 feet squared per day and a storage coefficient of 0.0045. The relationship between drawdown and distance from the pumping well for various time periods is shown in figure 14.

The curves in figure 14 are based on the assumptions that the aquifer is homogenous, isotropic, infinite in areal extent, and uniform in permeability and thickness, and that the discharge is from a single well. The Navajo Sandstone does not satisfy the above assumptions, and discharge in the amounts specified would result from withdrawal from a well field rather than a single well. Nevertheless, the theoretical drawdown projections give an order-of-magnitude estimate of effects of withdrawal.

The calculation based on withdrawal of 40,000 acre-feet per year from the Navajo Sandstone where the transmissivity is 5,000 feet squared per day and the storage coefficient is 0.0045 indicates that the drawdown at 18.9 miles from the pumping area would be about 80 feet after 25 years and about 124 feet after 50 years. The drawdown 100 feet from the pumping area would be in excess of 1,164 feet after 50 years. Under conditions of withdrawal of 20,000 acre-feet per year from the Navajo Sandstone where the transmissivity is 10,000 feet squared per day and the storage coefficient is 0.0045, the drawdown 18.9 miles distant from the pumping area would be about 31 feet after 25 years and about 43 feet after 50 years. The drawdown 100 feet from the pumping area would be about 304 feet after 50 years. Because of the small values (about 8,300 to 16,900 acre-feet per year) of natural recharge to and discharge from the Navajo Sandstone in the Kaiparowits Plateau area, withdrawals of these magnitudes would cause water to be removed from storage rather than diverted from natural discharge.

The effects of large-scale withdrawal on stream discharge and water quality are site specific and cannot be generalized to the entire study area. Generally, where drawdown in the Navajo would intersect a perennial stream, streamflow would be reduced. Where drawdown would cause leakage from overlying formations, degradation of water quality in the Navajo would be possible.

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS FOR FURTHER STUDY

The Kaiparowits Plateau area is located in central Garfield and eastern Kane Counties of Utah, and north-central Coconino County of Arizona. The area covers about 4,850 square miles, and includes the Escalante River and Paria River drainages and smaller drainages to the Colorado River between the Escalante River and Paria River drainages. In terms of potential for development, the Navajo Sandstone of Triassic(?) and Jurassic age is the most important consolidated rock aquifer in the Kaiparowits Plateau area, followed in importance by the Entrada Sandstone of Jurassic age and the Wingate Sandstone of Triassic age. Principal areas of withdrawal of water from the

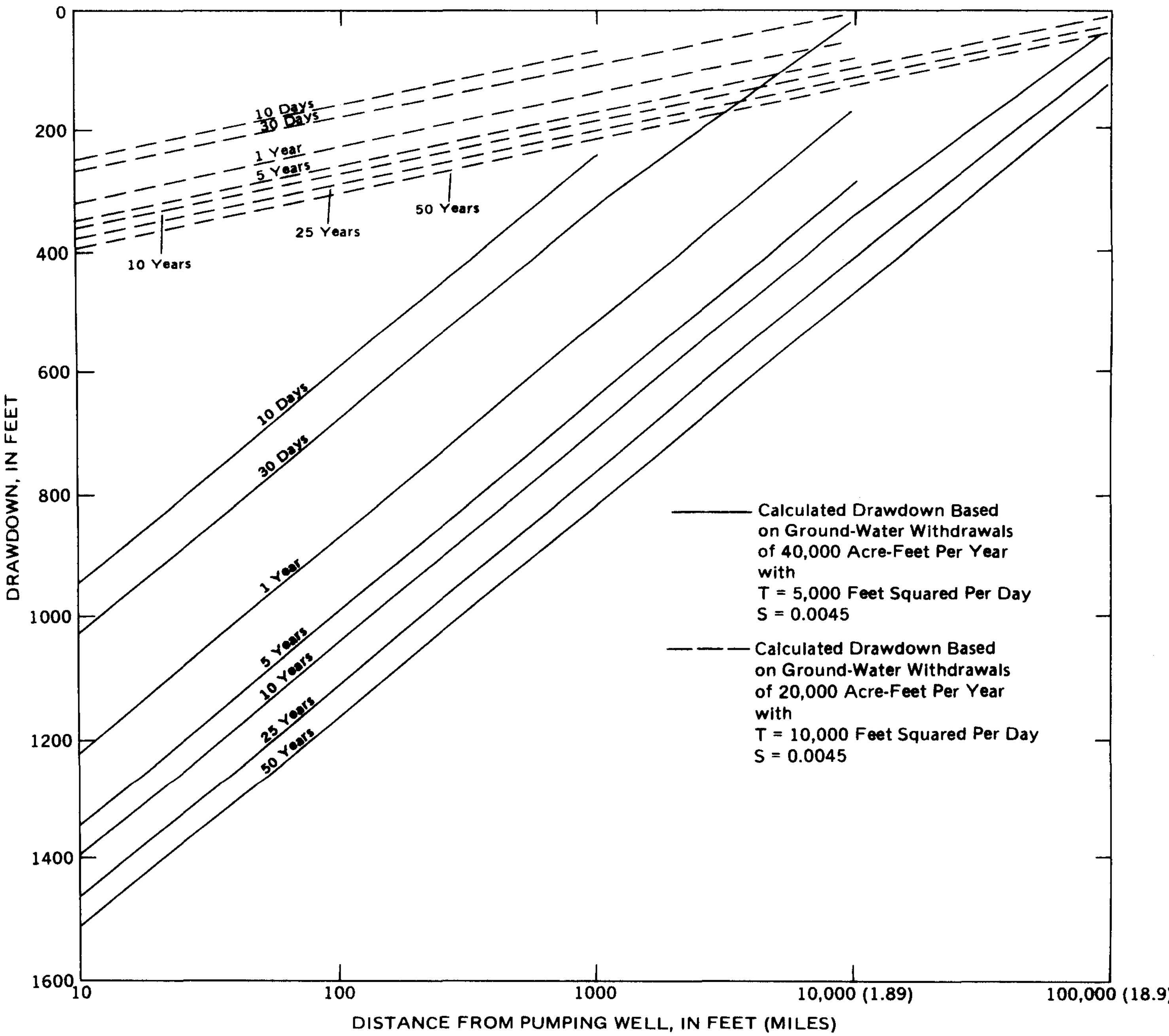

Figure 14.—Theoretical effect on water levels caused by withdrawals from the Navajo Sandstone.

Navajo Sandstone are near the town of Boulder and in the Paria Plateau area. Water from the Entrada Sandstone is withdrawn for irrigation or domestic use near the towns of Escalante, Cannonville, and Glen Canyon City. The Wingate Sandstone presently is not developed in the study area.

Annual recharge to and discharge from the Navajo Sandstone in the Kaiparowits Plateau area is estimated to be between 8,300 and 16,900 acre-feet. The total amount of water theoretically recoverable from storage in the Navajo Sandstone is estimated to be about 190 million acre-feet.

Chemical quality of water in the Navajo Sandstone ranges from fresh in areas where water-table conditions exist to slightly saline in areas where the aquifer is confined. In water-table areas, the predominant water type is calcium magnesium bicarbonate; in confined areas, it generally is sodium sulfate.

Inundation of Glen Canyon and tributary canyons by Lake Powell has caused a large increase in the altitude of the potentiometric surface near the lake. The ground-water system presently is out of equilibrium, and near the lakeshore ground-water movement is away from the lake. When equilibrium is re-established, the gradient will be to Glen Canyon as it was prior to Lake Powell, but the potentiometric surface will be higher and the gradient will be flatter.

Inundation has caused changes in ground-water chemistry near Lake Powell, primarily where the potentiometric surface has risen above the Navajo Sandstone-Carmel Formation contact. Major-ion chemistry has been altered, with the most significant change being an increase in sulfate concentration and a decrease in bicarbonate plus carbonate concentration. Arsenic in concentrations greater than U.S. Environmental Protection Agency drinking-water standards has been detected in three water-supply wells in the Glen Canyon National Recreation Area.

Because of the small estimated amount of water recharging to and discharging from the Navajo Sandstone, large withdrawals from the aquifer would come from water in storage rather than from diverted discharge. A large withdrawal would be accompanied by a large drawdown in the vicinity of the pumping well or well field.

Further study is needed in several areas in order to more accurately define the Navajo Sandstone ground-water system in the Kaiparowits Plateau area. The most obvious deficiency is the lack of information about the area beneath the Kaiparowits Plateau itself. Because of the great depth to the Navajo Sandstone, no water wells are completed in the Navajo under the plateau and information obtained during oil-test drilling is limited. Several of the existing oil-test holes need to be re-entered in order to obtain water levels in and water samples from the Navajo Sandstone. The data would aid in more accurately determining both the amount of water in storage and the quality of water in the Navajo. Such data are necessary before possible uses of the resource can be accurately determined.

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Table 11.--Drillers' logs of selected wells
[See "Numbering system for hydrogeologic-data sites", p. 5, and figure 2.]

Alt.: Altitude of land surface at well.
Thickness: Thickness of unit in feet.
Depth: Depth to base of unit in feet below land surface.

Material	Thickness	Depth
(C-37-3)24dda-1. Log by Leman Exploration Co. Alt. 5,900.		
Sand and fill, loose	16	16
Siltstone, very fine	324	340
Sand, medium white, coarse-grained	260	600
(C-37-3)24ddd-1. Log by Leman Exploration Co. Well completed to depth of 403 ft. Alt. 5,910.		
Fill and wash	8	8
Siltstone, very fine	352	360
Sandstone, coarse-grained	50	410
Sand, medium to fine-grained	110	520
(C-41-3)4bca-1. Log by Binning Drilling Co. Alt. 5,780.		
Silt and sand	24	24
Navajo Sandstone		
Sandstone, tan	11	35
Sandstone, orange	10	45
Sandstone, tan	5	50
Sandstone, rust	20	70
Sandstone, tan, hard	20	90
Sandstone, orange	25	115
Sandstone, tan, hard	20	135
Sandstone, orange	17	152
Sandstone, orange; seep of water	3	155
Sandstone, orange; 1 gallon per minute of water	15	170
Sandstone, tan, hard	15	185
Sandstone, pink; 3 gallons per minute of water	15	200
Sandstone, pink; 7 gallons per minute of water	20	220
Sandstone, tan, hard	5	225
Sandstone, pink	5	230
Sandstone, orange; 10 gallons per minute of water	10	240
Sandstone, orange; 13 gallons per minute of water	10	250
(C-41-4)23adb-1. Log by Clair Stephenson Drilling Co. Alt. 6,070.		
Sand and fill	10	10
Navajo Sandstone		
Sandstone	490	500
(C-43-1)3bac-1. Log by Clair Stephenson Drilling Co. Alt. 4,420.		
Soil, top	10	10
Carmel Formation		
Shale, light red	30	40
Shale, red	10	50
Shale and sandstone layers, gray	30	80
Shale and sandstone layers, red	20	100
Shale, red	80	180
Shale and sandstone layers, red; little water	95	275
Navajo Sandstone		
Sandstone, white; water	27	302
(C-43-1)4bad-1. Log by Ballard Well Drilling Co. Alt. 4,410.		
Sand	10	10
Sand and gravel	10	20
Carmel Formation		
Shale, brown	40	60
Shale, red	5	65
Sandstone	10	75
Shale, sandy	125	200
Navajo Sandstone		
Sandstone, white	205	405
Shale, red	10	415
(D-33-4)35cbc-1. Log by The Well Supply Co. Alt. 6,410.		
Soil	3	3
Conglomerate, loosely consolidated	52	55
Navajo Sandstone		
Sandstone, white	68	123
Sandstone, yellowish; water	210	333
(D-33-4)36abb-1. Log by The Well Supply Co. Alt. 6,525.		
Clay, cobbles, boulders	36	36
Navajo Sandstone		
Sandstone	289	325
(D-33-4)36bab-1. Log by The Well Supply Co. Alt. 6,570.		
Clay, sand, gravel, cobbles	46	46
Clay, cobbles, boulders	104	150
Navajo Sandstone		
Sandstone	250	400
(D-33-4)36cba-1. Log by The Well Supply Co. Alt. 6,730.		
Cobbles, hardpan	20	20
Navajo Sandstone		
Sandstone	515	535
(D-33-5)31adc-1. Log by The Well Supply Co. Alt. 6,360.		
Sand	35	35
Boulders	13	48
Navajo Sandstone		
Sandstone	352	400
(D-34-4)1cad-1. Log by The Well Supply Co. Alt. 6,320.		
Alluvium		
Clay, gravel, cobbles, boulders, hardpan	175	175
Navajo Sandstone		
Sandstone	33	208
Shale, red	2	210
(D-35-3)8aba-1. Log by Councilman Well Drilling Co. Alt. 5,810.		
Sand, loose	6	6
Sand, soft	10	16
Sand	10	26
Sandstone	10	36
Silt, mud, soft	10	46
Entrada Sandstone		
Sandstone, white	30	76
Sandstone, white; water	10	86
Sandstone, white	26	112
(D-35-3)8abb-1. Log by The Well Supply Co. Alt. 5,830.		
Entrada Sandstone		
Sandstone, yellow-gray	82	82
Sandstone, gray-blue	113	195
Sandstone, grading into bentonite	10	205
(D-35-3)29bbd-1. Log by The Well Supply Co. Alt. 5,840.		
Entrada Sandstone		
Sandstone, red	48	48
Sandstone, white	4	52
Sandstone, red	88	140
Sandstone, white	20	160
Sandstone; damp	68	228
Sandstone, red	63	291
(D-40-8)7bdc-1. Log by The Well Supply Co. Alt. 4,480.		
Allvuium	42	42
Entrada Sandstone	42	84
Carmel Formation	196	280
Navajo Sandstone	142	422
(D-43-1)2bda-1. Log by Ray Parnell Drilling Co. Alt. 4,510.		
Surface sand	15	15
Carmel Formation		
Sandstone, red	20	35
No record	10	45
Shale, sandy, red	23	68
Sandstone, red	27	95
Sandstone, brown	9	104
Sandstone, red	26	130
Shale, sandy, red	5	135
Sandstone, brown	5	140
(D-43-1)2bda-1.--Continued		
Carmel Formation--Continued		
Sandstone, gray	15	155
Shale, red	5	160
Navajo (?) Sandstone		
Sandstone, red	15	175
Sandstone, gray	180	355
Sandstone, red	25	380
Sandstone, white	5	385
Sandstone, pink	10	395
Sandstone, white	20	415
Sandstone, red	80	495
Sandstone, white	20	515
Sandstone, pink	40	555
Sandstone, red	40	595
Sandstone, white	25	620
Sandstone, pink	30	650
Sandstone, gray	70	720
Sandstone, white	40	760
Sandstone, red	18	778
(D-43-1)2bdd-1. Log by Ray Parnell Drilling Co. Alt. 4,520.		
Sand	10	10
Carmel Formation		
Shale, sandy, red	52	62
Sandstone, brown	63	125
Shale, sandy, red	15	140
Navajo (?) Sandstone		
Sandstone, brown	20	160
Sandstone, light red	40	200
Sandstone, white	50	250
Sandstone, light red	20	270
Sandstone, white	25	295
Sandstone, light red	35	330
Sandstone, white	15	345
Sandstone, light red	10	355
Sandstone, white	12	367
Sandstone, red	8	375
Sandstone, white	5	380
Sandstone, red	95	475
Sandstone, white	100	575
Sandstone, light red	25	600
Sandstone, pink	45	645
Sandstone, white	120	765
Sandstone, pink	17	782
(D-43-1)2cab-1. Log by San Diego Pump and Well Drillers, Inc. Alt. 4,530.		
Sand, loose, red	19	19
Caliche	13	32
Carmel Formation		
Sand and clay, loose, red	11	43
Sandstone, gray	14	57
Sandstone, red, firm	65	122
Clay, red, very soft	12	134
Sandstone, red, soft	14	148
Navajo (?) Sandstone		
Sandstone, white	28	176
Sandstone, red	22	198
Sandstone, white	39	237
Sandstone, red, hard	46	283
Sandstone, dark red	19	302
Sandstone, light pink, very soft	12	314
Sandstone, red	12	326
Sandstone, white	8	334
Sandstone, red	14	348
Sandstone, white	21	369
Sandstone, light red, very hard	5	374
Sandstone, dark red, firm	22	396
Sandstone, red, soft	16	412
Sand, loose, red, and clay, white, sticky	9	421
Sandstone, white, firm; water	71	492
Sandstone, white, in layers of hard and soft material	18	510
Sandstone, light red, fine texture	12	522
Sandstone, white, clean	7	529
Sandstone, red, broken; water increases	28	557
Sandstone, red, hard	35	592
Sandstone, white, very soft	14	606
Sandstone, white, hard, very consolidated	14	620

Material	Thickness	Depth
(D-43-2)13cdd-1. Log by San Diego Pump and Well Drillers, Inc. Well completed to depth of 594 ft. Alt. 4,000.		
Sand, blow	10	10
Sand, blow, small gravel, clay	6	16
Sand and gravel, cemented	22	38
Entrada Sandstone		
Sandstone, white	124	162
Sandstone, green and blue	14	176
Sandstone, light green and white	49	225
Sandstone, white, soft	27	252
Sandstone, white, firm	129	381
Sandstone, white, fractured, layers of light brown sand; water	31	412
Sandstone, white, broken, and clay	66	478
Sandstone, white, firm	85	563
Sandstone, brown, hard	15	578
Sandstone, pebbles, water washed; water level rose from 412 to 322 feet	5	583
Sandstone, white, firm	11	594
Carmel Formation		
Clay and bentonite, very soft, hole will not stay open	11	605
(D-43-2)13dcd-1. Log by H and M Exploration Co. Well completed to depth of 590 ft. Alt. 3,950.		
Alluvium	5	5
Chert pebbles in sandstone matrix	1	6
Sand, gray, fine-grained	5	11
Conglomerate	3	14
Sand, white	1	15
Conglomerate with bright red chert pebbles	2	17
Entrada Sandstone		
Sandstone, white, very fine-grained	13	30
Sandstone, yellow, very fine-grained	3	33
Sandstone, white, very fine-grained	19	52
Sandstone, green	2	54
Sandstone, white	16	70
Sandstone, green; damp	11	81
Sandstone, white-gray	99	180
Sandstone, gray-brown	159	339
Bentonite	3	342
Sandstone, white-gray	10	352
Sandstone, gray-white; water at 352-354, 590-661 feet; oil at 470-480 feet; hole caved back to 590 feet	309	661
(D-43-2)14bab-1. Log by Harry H. Morris. Well completed to depth of 537 ft. Alt. 4,128.80.		
Sand, blow, red	30	30
Entrada Sandstone		
Sandstone, white	43	73
Sandstone, light red	25	98
Sandstone, light brown	9	107
Sandstone, light blue and brown	102	209
Sandstone, white, clean	4	213
Sandstone, white	7	220
Sandstone, brown	23	243
Sandstone, white; water seepage	24	267
Sandstone, white	45	312
Clay, red	30	342
Sandstone, white, very hard	18	360
Clay, red	28	388
Sandstone and clay, red	10	398
Sandstone, red, soft	39	437
Sandstone, white, soft	15	452
Clay, red, loose and broken	15	467
Sandstone, white; water-bearing	67	534
Sand and clay, white	2	536
Carmel Formation		
Clay, red, sticky, loose and caving; well caved to 537 feet	61	597
(D-44-3)2bdo-1. Log by The Well Supply Co. Alt. 3,820.		
Sand	12	12
Entrada Sandstone (called Wahweap Formation by driller)	86	98
(D-44-3)2bdo-1.--Continued		
Carmel Formation		
Clay, red-brown	57	155
Clay, purple-gray	34	189
Clay, purple-gray, sandy	21	210
Clay, red, hard	35	245
Clay, sandy pebbles, red-brown	40	285
Shale, red	6	291
Sandstone, red-brown-yellow	60	351
Sandstone, red-orange	34	385
Mudstone, brown	5	390
Shale, hard	58	448
Navajo Sandstone		
Sandstone	142	590
Sandstone, very hard	22	612
Sandstone	40	652
(A-39-4)6cbb-1. Log by Mersfelder Drilling Co. Alt. 6,610.		
Navajo Sandstone		
Sandstone, pink	520	520
Kayenta Formation		
Sandstone, limestone, shale	70	590
Moenave Formation		
Sandstone and shale, pink; water at about 650 feet	110	700
(A-40-5)5ccc-1. Log by Mersfelder Drilling Co. Alt. 6,160.		
Navajo Sandstone		
Sandstone	950	950
Kayenta Formation		
Sandstone, limestone, shale	70	1,020
Moenave Formation		
Sandstone, shale	320	1,340
(A-40-5)12ddb-1. Log by Mersfelder Drilling Co. Alt. 6,210.		
Navajo Sandstone		
Sandstone, coarse, light colored	1,420	1,420
Kayenta Formation		
Silt and clay, fine, red	12	1,432
Moenave (?) Formation		
Sandstone, fine, buff to light red	36	1,468
(A-40-6)3ccc-1. Log by Mersfelder Drilling Co. Well completed to depth of 1,802 ft. Alt. 6,150.		
Navajo Sandstone		
Sandstone	1,300	1,300
Kayenta Formation		
Sandstone, limestone, shale	60	1,360
Moenave (?) Formation		
Sandstone, shale, siltstone; well completed to or caved back to 1,802 feet	450	1,810
(A-41-8)4dda-1. Log by Perry Brothers Drilling Co. Alt. 4,160.		
Sand, loose	3	3
Entrada Sandstone		
Sandstone, white	77	80
Sandstone, light red	10	90
Sandstone, white	145	235
Sandstone, light red	40	275
Carmel Formation		
Sandstone, red	335	610
Sandstone, light red; hole will not hold water	240	850
Sandstone, light red, loose; hole caving, first water encountered	10	860
Navajo Sandstone		
Sandstone, light red, very clean	30	890
Sandstone, light red	35	925
(A-41-8)14bca-1. Log by Wininger Drilling Co. Alt. 4,112.		
Loose sand	8	8
Caliche	22	30
Carmel Formation		
Sandstone, alternating layers of brown and hard light gray, each layer 5 feet thick or less	335	365
Navajo Sandstone		
Sandstone, light brown	450	815
Sandstone, brown, broken; water at 885 feet and rose to 870 feet	215	1,030
Sandstone, brown	170	1,200
(A-41-8)14bcb-1. Log by Wininger Drilling Co. Alt. 4,120.		
Sandstone, reddish-brown; water first noticed at 885 feet and stood at 880 while drilling was being completed	885	885
Sandstone, reddish-brown, cleaner and coarser than from 0 to 885 feet	70	955
Sandstone, reddish-brown	40	995
Sandstone, reddish-brown, fine with silt	5	1,000
Sandstone, reddish-brown, broken, with layers of coarser sandstone	145	1,145
Sandstone, reddish-brown, with silt or mudstone	355	1,500
(A-41-8)23dac-1. Log by Wininger Drilling Co. Alt. 3,917.		
Sand, blow	18	18
Navajo Sandstone		
Sandstone, light brown, with hard ribs or ledges, occasional pockets of soft sand or silt; water at 735 feet	767	785
Sandstone, cleaner; increase in water	125	910
(A-41-8)23dcd-1. Log by Wininger Drilling Co. Alt. 3,982.		
Navajo Sandstone		
Sandstone, broken	6	6
Sandstone, brown, very uniform	554	560
Sandstone, gray, dense	240	800
Sandstone, gray, softer; water	80	880
Sandstone, red	35	915
Sandstone, hard, dense	10	925
Sandstone, red	65	990
Sandstone, gray	20	1,010
Sandstone, broken	15	1,025
Sandstone, hard	5	1,030
Sandstone, brown, more silt or mud	70	1,100
Sandstone, brown; drilling muddy	65	1,165
Sandstone, brown, and silt	120	1,285
(A-42-8)32cdd-1. Log by Larry Dalton. Alt. 4,100.		
Hardpan	4	4
Sand, white, loose	14	18
Entrada Sandstone		
Sandstone, white, with bentonite layers	167	185
Sandstone, gray, medium hard	5	190
Carmel Formation		
Shale, red, medium hard	129	319
Shale, red, soft and sandy	56	375
Shale, red and white, very hard	3	378
Shale, red	7	385
Sandstone, red, soft	55	440
Sandstone, red, hard	70	510
Shale, red, sandy, very hard	71	581
Sandstone, red, with shale layers	3	584
Shale, light red, soft	69	653
Navajo Sandstone		
Sandstone, red; water at 653 feet, rose to static level of 604 feet	137	790
Shale, red, hard	18	808
Sandstone, red, soft	78	886
Sandstone, hard	22	908
Sandstone, hard to medium hard, layers	22	930
Sandstone, very hard	5	935
(A-42-8)35dab-1. Log by Wininger Drilling Co. Alt. 3,736.		
Caliche	15	15
Conglomerate: sand, gravel, boulders	30	45
Sandstone, hard, gray	375	420
Sandstone, softer; water	20	440
Sandstone; water	35	475
Sandstone, with clay, harder	15	490
Sandstone, light gray, soft; water	110	600

Material	Thickness	Depth
(A-42-8)35dab-1.--Continued		
Sandstone; water	25	625
Sandstone, clayey and silty	50	675
Note: Resistivity log of well indicates that the top of the Navajo Sandstone is at 280 feet, and that the total depth of the well is 603 feet.		
(A-42-8)35dab-2. Log by Wininger Drilling Co. Well completed to depth of 620 ft. Alt. 3,735.		
Caliche	12	12
Conglomerate: sand, gravel, boulders	30	42
Sandstone, red, hard	53	95
Sandstone, red, softer	165	260
Navajo Sandstone		
Sandstone, gray	140	400
Sandstone; water	40	440
Sandstone, red	30	470
Sandstone; water	5	475
Sandstone, light gray	160	635
Sandstone, red	5	640
Note: Well either completed to or caved to depth of 620 feet.		
(A-42-8)35dad-1. Log by Wininger Drilling Co. Alt. 3,742.		
Sand	4	4
Caliche	18	22
Conglomerate: sand, clay, gravel, and boulders	33	55
Sandstone, reddish-brown	275	330
Clay, soft, silty; water seep	15	345
Sandstone, with clay layers, or sandy clay	130	475
Sandstone; water	90	565
Clay, sandy	60	625
(A-42-8)36ccc-2. Log by Perry Brothers Drilling Co. Alt. 3,760.		
Carmel Formation		
Shale, red, sandy	20	20
Sandstone, red	40	60
Shale, red	5	65
Sandstone, red	135	200
Shale, red, sandy	7	207
Navajo Sandstone		
Sandstone, red	13	220
Sandstone, light red	130	350
Sandstone, red	20	370
Sandstone, light red	40	410
Sandstone, brown	10	420
Sandstone, light red	30	450
Sandstone, light brown	50	500
Sandstone, light red	80	580
Sandstone, brown	50	630
Sandstone, light red	73	703

[Abbreviations used in headings are as follows: FT, feet; IN, inches; GAL/MIN, gallons per minute; (GAL/MIN)FT, gallons

Number: See "Numbering system for hydrogeologic-data sites", p. 5, and figure 2
Owner: U.S. BLM, U.S. Bureau of Land Management.
Finish: P, perforated; X, open hole without casing.
Principal aquifer: 220GLNC, Glen Canyon Group; 220NVJO, Navajo Sandstone; 221ENRD, Entrada Sandstone.
Water level: D, dry hole; L, geophysical log; R, reported; S, measured with steel tape; T, measured with electric tape.
Discharge: B, measured with bailer; C, measured with current meter; R, reported.
Types of logs available: C, caliper; D, driller's; E, electric; J, gamma ray; N, neutron; T, temperature; U, gamma-gamma.
Other data available: QW (water quality): B, common ions; P, physical, common ions, and trace elements; WL (water level):

NUMBER	OWNER	DATE COMPLETED	ALTITUDE OF LAND SURFACE (FT)	DEPTH OF WELL (FT)	CASING DIAMETER (IN)	DEPTH CASED (FT)	DEPTH TO FIRST OPENING (FT)	FINISH	PRINCIPAL AQUIFER	DEPTH TO AQUIFER (FT)
										WELLS
(C-37- 3)24DDA- 1	THOMPSON, GEORGE W.	1972	5900	600	4	570	510	P	221ENRD	340
24DDD- 1	STOCK, BERT & IRMA	02/25/72	5910	403	4	403	373	P	221ENRD	360
(C-41- 3) 4BCA- 1	U.S. BLM	06/18/68	5780	250	6	250	150	P	220NVJO	24
(C-41- 4)23ADB- 1	DO.	09/07/78	6070	500	6.63	20	20	X	220NVJO	10
(C-43- 1) 3BAC- 1	DO.	12/13/74	4420	302	6	300	275	P	220NVJO	275
4BAD- 1	GREENE & WEEDE INVESTMENT	08/04/71	4410	415	8	220	220	X	220NVJO	200
(D-33- 4)35BBD- 1	NELSON, MARK	01/31/75	6480	500	16	6	6	X	220NVJO	0
35CBB- 1	PECK, WILLIAM H.	07/18/71	6380	306	14	80	30	X	220NVJO	68
35CBC- 1	DO.	10/27/70	6410	333	6.63	75	75	X	220NVJO	55
36ABB- 1	CROSBY, SAM & VIVIAN	05/15/75	6525	325	8	36	36	X	220NVJO	36
36BAB- 1	DO.	07/28/77	6570	400	8	150	150	X	220NVJO	150
36CBA- 1	PRESTON, ROBERT L.	03/04/74	6730	535	8	23	23	X	220NVJO	20
(D-33- 5)31ADC- 1	CLARKSON, DALE E.	02/29/80	6360	400	14	52	52	X	220NVJO	48
(D-34- 4) 1CAD- 1	JEPSON, ALFRED	03/28/77	6320	210	6	180	180	X	220NVJO	175
(D-35- 3) 8ABA- 1	BRUBAKER, RONALD W.	09/24/77	5810	112	6	60	60	X	221ENRD	46
8ABB- 1	FORD, HAROLD H.	03/29/74	5830	205	8	27	27	X	221ENRD	0
29BBD- 1	SCHOW, JOSEPH B.	12/22/76	5840	291	6	291	100	P	221ENRD	0
(D-35- 4)20CCA- 1	SCHULTZ, BUTCH	01/01/80	5950	800	8	150	150	X	220NVJO	145
(D-40- 8) 7BDC- 1	U.S. BLM	10/05/80	4480	422	6	422	380	P	220NVJO	280
(D-43- 1) 2BDA- 1	CONSUMERS AGENCY, INC.	09/27/57	4510	778	10	15	15	X	220NVJO	280
2BDD- 1	DO.	09/16/57	4520	782	10	30	30	X	220NVJO	--
2CAB- 1	DO.	08/31/59	4530	620	10	42	42	X	220NVJO	--
(D-43- 2)13CDD- 1	TAYLOR, DEE R.	12/25/59	4000	590	10	29	29	X	221ENRD	38
13DCD- 1	DO.	07/18/66	3950	590	11	15	15	X	221ENRD	17
14BAB- 1	CONSUMERS AGENCY, INC.	--	4128.80	537	10	33	--	X	--	30
(D-43- 3)32DCA- 2	TAYLOR, LES	--	3984.34	780	16	--	--	--	--	--
(D-44- 3) 2BDC- 1	U.S. NATIONAL PARK SERVICE	11/19/80	3820	652	8	652	495	P	220NVJO	448
(D-44- 4) 8BBC- 1	U.S. BUREAU OF RECLAMATION	--	3722.87	800	20	--	--	--	220NVJO	--
8BBD- 1	DO.	1950	3760	208	--	--	--	--	--	--
										WELLS IN
(A-39- 4) 6CBB- 1	VERMILION CLIFFS CC	08/ /61	6610	700	6	--	--	--	220GLNC	0
(A-40- 4) 5DAC- 1	SANDERS	1950	6000	300	--	--	--	--	220NVJO	--
5DAC- 2	DO.	1950	6000	700	--	--	--	--	220NVJO	--
19BAB- 1	SANDERS, A. P.	04/17/60	6050	610	--	--	--	--	220GLNC	372
27BBC- 1	VERMILION CLIFFS CC	07/ /52	6330	920	6	550	--	P	220NVJO	0
(A-40- 5) 5CCC- 1	DO.	06/ /60	6160	1340	5	1000	1000	X	220GLNC	0
12DDB- 1	FINDLAY, A.D.	07/10/62	6210	1468	4	--	--	--	220NVJO	0
33CBC- 1	DO.	--	6400	1175	--	--	--	--	220NVJO	0
(A-40- 6) 3CCC- 1	VERMILION CLIFFS CC	12/11/59	6150	1802	4	1762	1762	X	220NVJO	0
(A-41- 4)14CBB- 1	--	1954	5580	600	--	--	--	--	220NVJO	--
16CBB- 1	--	1954	5730	700	--	--	--	--	220NVJO	--
28ADA- 1	SANDERS, A.	--	5875	920	--	--	--	--	220GLNC	--
(A-41- 8) 4DDA- 1	CANYON TOURS	10/20/61	4160	925	8	793	793	X	220NVJO	860
14BCA- 1	ARIZONA DEPT. OF TRANSPORTATION	02/ /58	4112	1200	14	1030	880	P	220NVJO	365
14BCB- 1	U.S. NATIONAL PARK SERVICE	10/ /57	4120	1500	10.75	11	11	X	220NVJO	365
23DAC- 1	U.S. BUREAU OF RECLAMATION	01/ /58	3917	910	7	910	755	P	220NVJO	18
23DCD- 1	DO.	07/ /57	3982	1285	18	6	6	X	220NVJO	0
(A-42- 8)32CDD- 1	GREEN, BILL	10/15/72	4100	935	12	935	607	P	220NVJO	653
35DAB- 1	U.S. BUREAU OF RECLAMATION	07/ /58	3736	603	20	76	76	X	220NVJO	280
35DAB- 2	U.S. NATIONAL PARK SERVICE	03/ /58	3735	620	16	416	416	X	220NVJO	260
35DAD- 1	U.S. BUREAU OF RECLAMATION	01/ /58	3742	625	14	625	475	P	220NVJO	--
35DCD- 1	U.S. NATIONAL PARK SERVICE	02/ /74	3900	800	--	--	430	--	220NVJO	--
36CBC- 1	U.S. BUREAU OF RECLAMATION	01/ /59	3735	398	20	77	77	X	220NVJO	233
36CCC- 1	CANYON TOURS	10/ /57	3840	625	8	500	500	X	220NVJO	--
36CCC- 2	U.S. NATIONAL PARK SERVICE	02/ /61	3760	703	13.37	503	503	X	220NVJO	207

selected water wells
per minute per foot of drawdown; UMHO/CM AT 25 °C, micromhos per centimeter at 25 degrees Celsius; °C, degrees Celsius.]

I, intermittent; M, monthly; O, one-time measurement; R, continuous recorder.

WATER LEVEL (FT)		DATE WATER LEVEL MEASURED	DISCHARGE (GAL/MIN)	DRAW-DOWN (FT)	SPECIFIC CAPACITY [(GAL/MIN) FT]	DATE DISCHARGE MEASURED	SPECIFIC CONDUCTANCE (UMHO/CM AT 25°C)	TEMPERATURE (°C)	DATE QUALITY PARAMETERS MEASURED	TYPES OF LOGS AVAILABLE	OTHER DATA AVAILABLE QW	WL
IN UTAH												
41.91	S	08/12/81	--	--	--	--	--	--	--	D	--	O
44.97	S	08/12/81	--	--	--	--	--	16.5	08/12/81	D	--	O
134	R	06/18/68	13 R	85	0.2	06/18/68	415	12.5	06/12/81	D	P	O
	D	--	--	--	--	--	--	--	--	D	--	--
140.72	S	02/25/81	60 R	20	3.0	12/13/74	1520	16.5	02/25/81	D	P	M
110	R	08/04/71	100 B	0	--	08/04/71	--	--	--	D	--	--
160.78	S	01/27/81	30 R	--	--	01/31/75	415	11.5	04/23/81	--	P	M
80	R	07/18/71	40 R	--	--	07/18/71	390	13.0	08/09/79	D	--	O
143.98	S	03/02/81	20 R	--	--	10/27/70	--	--	--	D	--	M
235.77	S	04/03/81	15 R	10	1.5	05/15/75	640	12.5	09/01/81	D	P	--
249.85	S	05/13/81	60 R	--	--	07/28/77	--	--	--	D	--	M
445.61	S	04/28/81	15 R	--	--	03/04/74	--	--	--	D	--	O
162.90	S	01/27/81	40 R	--	--	02/29/80	310	17.0	09/01/81	D	P	M
140.55	S	01/27/81	20 R	--	--	03/28/77	430	12.5	09/01/81	D	P	M
28.51	S	09/02/81	.50 B	32	<.1	09/24/77	810	13.5	09/03/81	D	P	O
57.69	S	09/02/81	.17 R	--	--	03/29/74	--	--	--	D	--	O
44.27	S	09/03/81	.40 B	207	<.1	12/22/76	--	--	--	D	--	O
669	L	08/30/81	--	--	--	--	--	15.5	08/30/81	T	--	O
376.75	S	03/05/81	15 B	45	.3	10/05/80	--	--	--	D	--	--
470	R	09/27/57	20 R	0	--	09/27/57	--	--	--	D	--	I
461.20	S	05/22/81										
485	R	09/16/57	20 R	0	--	09/16/57	960	16.0	09/26/79	D	P	O
490	R	08/31/59	--	--	--	--	--	--	--	D	--	I
479.50	S	05/22/81										
322	R	12/25/59	25 B	0	--	12/25/59	--	--	--	D	--	I
212.03	S	06/18/81										
230	R	07/18/66	--	--	--	--	600	20.0	06/18/81	D	P	O
230.33	S	10/10/63	--	--	--	--	--	--	--	D	--	R
310.21	S	10/10/63	--	--	--	--	--	--	--	--	--	R
107.53	S	04/27/81	150 R	50	3.0	11/19/80	--	--	--	D	--	I
357.07	S	07/15/64	--	--	--	--	--	--	--	--	--	R
66.39	S	11/14/81	--	--	--	--	--	--	--	--	--	M
ARIZONA												
520	R	06/20/70	5.0 B	5	1.0	08/ /61	500	12.0	08/05/76	D	P	I
526.50	T	08/05/76										
	D	--	--	--	--	--	--	--	--	--	--	--
	D	--	--	--	--	--	--	--	--	--	--	--
515	R	04/17/60	12 B	20	.6	04/17/60	--	--	--	--	--	O
860	R	07/ /69	5.0 R	--	--	07/ /69	--	--	--	--	--	O
1100	R	07/ /69	5.0 R	--	--	07/ /69	--	--	--	D	--	O
1310	R	07/10/62	15 B	--	--	07/10/62	250	12.0	08/05/76	D	P	O
950	R	06/14/51	--	--	--	--	300	--	08/05/76	--	P	O
1500	R	07/ /69	3.0 R	--	--	12/11/59	--	--	--	D	--	O
	D	1954	--	--	--	--	--	--	--	--	--	--
	D	1954	--	--	--	--	--	--	--	--	--	--
700	R	06/ /72	--	--	--	--	275	16.0	08/06/76	--	B	O
849	R	10/14/61	--	--	--	--	--	--	--	D	P	I
492.20	S	06/18/81										
870	R	02/ /58	180 R	--	--	02/ /58	--	--	--	D	P	I
485.17	S	02/09/81										
880	R	10/ /57	100 R	--	--	10/ /57	--	--	--	C, D, E, J, N, T, U	B	I
378.1	L	08/28/81	30 R	--	--	--	--	--	--	C, D, J, N, T	P	M
521.8	L	08/27/81	34 R	--	--	07/ /57	--	--	--	C, D, E, J, N, T, U	P	--
604	R	10/15/72	600 R	171	3.5	10/15/72	--	--	--	D	P	I
395	R	07/ /58	--	--	--	--	--	--	--	C, D, E, J, N, T, U	B	M
402	R	03/ /58	--	--	--	--	--	--	--	D	P	--
423	R	01/ /58	1000 R	--	--	01/ /58	--	--	--	D	B	O
285	R	02/ /74	--	--	--	--	--	--	--	--	P	O
82.00	S	07/22/76	1200 R	--	--	01/ /59	--	--	--	E, J, N, T, U	B	M
410	R	10/ /57	100 R	8	12.5	10/ /57	2050	20.0	12/05/58	--	B	O
453	R	08/01/61	275 C	25	11.0	02/ /61	--	--	--	D	P	O
73.53	S	08/07/79										

Table 13.--Water levels in selected observation wells

[Water levels are in feet below land surface. From water-level records except E, estimated; L, log; R, reported; S, steel-tape measurement; T, electric-tape measurement.]

Well number: See "Numbering system for hydrogeologic-data sites", p. 5, and figure 2.
Altitude (Alt.) of land surface: Surveyed altitudes given in feet and decimal fractions; altitudes interpolated from U.S. Geological Survey topographic maps given in feet.

WELLS IN UTAH

(C-43- 1) 3BAC- 1 ALT. 4,420

DEC 13, 1974	148. R	APR 25, 1981	141.67 S	JUL 29, 1981	153.79 S	NOV 16, 1981	140.94 S
FEB 25, 1981	140.72 S	MAY 26	143.00 S	AUG 29	141.73 S	APR 12, 1983	140.42 S
MAR 24	140.94 S	JUN 24	144.04 S	OCT 02	142.46 S		

(D-33- 4)35BBD- 1 ALT. 6,480

JAN 27, 1981	160.78 S	APR 28, 1981	161.25 S	JUL 30, 1981	165.53 S	MAR 10, 1983	160.94 S
MAR 02	160.41 S	MAY 13	161.06 S	SEP 01	166.55 S		
APR 03	160.41 S	25	163.05 S	NOV 13	162.80 S		
23	160.67 S	JUN 23	161.09 S	MAR 03, 1982	161.18 S		

(D-33- 4)35CBC- 1 ALT. 6,410

AUG 09, 1979	146.61 S	APR 03, 1981	143.98 S	JUN 23, 1981	145.33 S	OCT 01, 1981	144.90 S
JAN 26, 1981	144.30 S	28	144.24 S	JUL 30	145.15 S	NOV 13	144.93 S
MAR 02	143.98 S	MAY 25	144.69 S	SEP 01	144.75 S		

(D-33- 4)36BAB- 1 ALT. 6,570

NOV 13, 1980	249.29 S	MAY 25, 1981	249.93 S	JUL 30, 1981	249.77 S	OCT 01, 1981	249.70 S
MAY 13, 1981	249.85 S	JUN 23	249.81 S	SEP 01	250.48 S		

(D-33- 5)31ADC- 1 ALT. 6,360

JAN 27, 1981	162.90 S	MAY 25, 1981	164.40 S	SEP 01, 1981	168.02 S	MAR 10, 1983	169.02 S
MAR 02	163.14 S	JUL 01	164.97 S	OCT 01	166.71 S		
APR 03	163.56 S	30	208.93 S	NOV 13	166.59 S		
28	164.10 S	AUG 13	177.97 S	MAR 03, 1982	166.76 S		

(D-34- 4) 1CAD- 1 ALT. 6,320

JAN 27, 1981	140.55 S	APR 28, 1981	142.98 S	JUL 30, 1981	143.47 S	NOV 13, 1981	141.75 S
MAR 02	141.55 S	MAY 25	143.41 S	SEP 01	143.22 S		
APR 03	142.18 S	JUN 23	143.07 S	OCT 01	142.89 S		

(D-43- 2)14BAB- 1 ALT. 4,128.80

OCT 10, 1963	230.33	SEP 05, 1964	228.77	AUG 31, 1965	228.40	SEP 20, 1966	227.15
15	230.35	10	228.96	SEP 05	228.30	25	227.07
20	230.33	15	228.82	10	228.38	30	227.04
25	230.35	20	228.97	15	228.19	NOV 05	226.94
31	230.30	25	229.86	20	228.33	30	227.10
NOV 05	230.25	30	228.82	25	228.20	DEC 05	226.69
10	230.37	OCT 05	228.87	30	228.32	10	227.31
15	230.32	10	228.90	OCT 05	228.27	15	227.13
20	230.10	15	228.74	10	228.25	20	226.92
25	230.37	20	228.77	15	227.95	25	226.76
30	230.45	25	228.76	20	228.32	31	226.81
DEC 05	230.38	31	228.71	25	228.39	JAN 05, 1967	226.70
10	229.77	DEC 15	228.56	31	228.31	10	227.26
15	230.35	20	228.82	NOV 05	228.18	15	226.89
20	230.22	25	228.40	10	228.05	20	226.77
25	230.33	31	228.73	15	228.10	25	226.55
31	230.35	JAN 05, 1965	228.85	20	228.14	31	226.66
JAN 05, 1964	230.20	10	228.87	25	227.88	FEB 05	226.73
10	230.00	15	228.90	30	228.23	10	226.61
15	230.10	20	228.51	DEC 05	228.32	15	226.45
20	230.00	25	228.36	10	227.81	20	226.64
25	230.35	31	228.42	15	227.80	25	226.60
31	230.35	FEB 05	228.52	20	228.38	28	226.97
FEB 05	229.90	10	228.31	25	228.17	MAR 05	226.37
10	229.12	15	228.59	31	228.05	10	226.45
15	228.97	20	228.12	JAN 05, 1966	228.30	15	226.71
20	229.20	25	228.75	10	228.20	20	226.61
25	228.93	28	228.34	15	227.97	25	226.43
29	228.94	MAR 05	228.74	20	227.93	31	226.37
MAR 05	228.93	10	228.51	25	228.01	APR 05	226.52
10	229.12	15	228.49	31	227.80	10	226.43
15	229.22	20	228.68	FEB 05	228.14	15	226.38
20	229.17	25	228.34	10	227.83	20	226.46
25	228.98	31	228.53	15	228.01	25	226.47
31	229.03	APR 05	228.49	20	228.15	30	226.42
APR 05	228.85	10	228.32	25	227.83	MAY 05	226.45
10	229.10	15	228.73	28	228.00	10	226.33
15	229.03	20	228.61	MAR 05	228.30	15	226.75
20	228.94	25	228.44	10	227.96	20	226.52
25	228.95	30	228.57	15	227.90	25	226.39
30	228.84	MAY 05	228.28	20	227.87	31	226.23
MAY 05	228.96	10	228.58	25	227.91	JUN 05	226.49
10	229.16	15	228.43	31	227.97	10	226.27
25	229.16	20	228.43	APR 05	228.02	15	226.46
31	228.97	25	228.35	10	227.74	20	226.49
JUN 05	228.92	31	228.31	15	228.06	25	226.43
10	228.97	JUN 05	228.46	20	227.70	30	226.42
15	228.92	10	228.43	25	228.00	JUL 05	226.32
20	228.97	15	228.19	30	227.88	10	226.40
25	229.09	20	228.48	JUN 30	227.57	15	226.39
30	229.03	25	228.19	JUL 05	227.46	20	226.33
JUL 05	228.90	30	228.34	10	227.45	25	226.43
10	229.03	JUL 05	228.38	15	227.38	31	226.33
15	228.99	10	228.33	20	227.28	AUG 05	226.41
20	228.93	15	228.42	25	227.34	10	226.45
25	228.93	20	228.31	AUG 05	227.18	15	226.29
31	228.93	25	228.38	10	227.12	20	226.27
AUG 05	229.04	31	228.44	15	227.33	25	226.32
10	228.88	AUG 05	228.30	20	227.27	31	226.35
15	228.86	10	228.40	25	227.32	SEP 05	226.20
20	228.78	15	228.32	31	227.14	10	226.27
25	228.93	20	228.34	SEP 10	227.13	15	226.26
31	228.79	25	228.33	15	227.09	20	226.25

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SEP 25, 1967	226.18	APR 20, 1969	224.73	FEB 05, 1971	223.18	MAR 20, 1974	219.86
30	226.17	JUN 05	224.72	10	223.51	25	219.88
OCT 05	226.13	10	224.48	15	223.18	31	219.73
10	226.15	15	224.64	20	223.88	APR 05	220.07
15	226.10	20	224.66	25	223.12	10	219.67
20	226.21	25	224.39	28	223.17	15	220.04
25	226.10	30	224.71	MAR 05	223.04	20	219.68
31	226.17	JUL 05	224.55	10	223.22	JUN 10	219.79
NOV 05	226.01	10	224.75	15	223.29	15	219.70
10	226.10	15	224.67	20	223.27	20	219.65
15	226.10	20	224.78	25	223.08	25	219.70
20	226.23	25	224.62	31	222.98	30	219.60
25	226.28	31	224.70	APR 05	223.41	JUL 05	219.52
30	225.84	AUG 05	224.54	10	223.16	10	219.44
DEC 05	225.97	10	224.50	15	222.85	15	219.52
10	226.06	15	224.63	20	222.98	20	219.48
15	225.79	20	224.59	25	222.88	25	219.34
20	225.65	31	224.43	30	223.27	31	219.24
25	226.20 E	SEP 05	224.35	MAY 05	223.02	AUG 05	219.14
31	225.99	10	224.51	10	223.24	10	219.07
JAN 05, 1968	226.05	15	224.44	15	223.17	15	219.04
10	225.88	20	224.31	20	223.04	20	218.88
15	225.96	25	224.43	25	223.12	25	218.96
20	226.08	30	224.33	31	223.08	31	218.82
25	225.64	OCT 05	224.37	JUN 05	223.24	SEP 05	218.83
31	225.77	10	224.14	10	223.05	10	218.71
FEB 05	226.04	15	224.31	15	223.05	15	218.87
10	225.64	20	224.43	20	223.19	20	218.74
15	225.71	25	224.60	25	223.14	25	218.62
20	225.72	31	224.50	30	223.18	30	218.70
25	225.83	NOV 05	224.70	JUL 05	223.13	OCT 05	218.45
29	225.86	JAN 15, 1970	224.05	10	223.16	10	218.44
MAR 05	225.60	20	224.23	15	223.00	15	218.61
10	225.48	25	224.06	20	223.17	20	219.28
15	225.70	31	224.16	25	223.10	25	219.44
20	225.71	FEB 05	224.07	31	223.13	31	219.16
25	225.58	10	224.15	AUG 05	223.09	NOV 05	219.20
31	225.55	15	223.98	10	223.07	10	219.18
APR 05	225.57	20	224.25	15	223.01	15	219.02
10	225.87	25	224.13	20	223.03	20	219.15
15	225.51	28	223.90	25	223.04	25	219.10
MAY 20	225.48	MAR 05	223.84	31	222.90	30	219.08
25	225.50	10	223.69	SEP 05	222.89	DEC 05	218.84
31	225.44	15	223.95	10	222.41	10	217.83
JUN 05	225.24	20	223.98	15	222.74	15	217.80
10	225.52	25	223.82	20	222.76	20	217.10 E
15	225.50	31	223.44	25	222.64	25	217.70 E
20	225.48	APR 05	223.05	30	222.55	31	217.70 E
25	225.35	10	223.18	OCT 05	223.01	JAN 05, 1975	217.70 E
30	225.12	15	223.67	10	222.94	10	217.70 E
JUL 05	225.17	20	223.70	15	222.48	15	217.70 E
10	225.16	25	223.84	20	222.99	20	217.60 E
15	225.31	30	223.94	25	222.60	25	217.60 E
20	225.19	MAY 05	223.99	31	222.79	31	217.60 E
25	225.24	10	223.64	NOV 05	222.80	FEB 05	217.60 E
31	225.30	15	224.06	10	222.99	10	217.60 E
AUG 05	225.26	20	223.73	15	222.55	15	217.60 E
10	225.31	25	223.88	20	222.92	20	217.60 E
15	225.45	31	223.82	DEC 31	222.70	25	217.40 E
20	225.43	JUN 05	223.83	FEB 10, 1972	222.41	28	217.40 E
25	225.22	10	223.56	15	222.31	MAR 05	217.40 E
31	225.21	15	223.80	20	222.51	10	217.40 E
SEP 05	225.30	20	223.85	25	222.23	15	217.30 E
10	225.26	25	223.91	29	222.14	20	217.30 E
15	225.07	30	223.64	MAR 05	222.41	25	217.30 E
20	225.01	JUL 05	223.91	10	222.45	31	217.20 E
25	225.37	10	223.86	15	222.36	APR 05	217.20 E
30	225.31	15	223.78	MAY 03	222.28	10	217.20 E
OCT 05	225.19	20	223.73	OCT 17	221.83	15	217.10 E
10	225.20	25	223.78	DEC 18	222.20	20	217.10 E
15	225.04	31	223.68	MAR 01, 1973	221.38	25	216.74
20	225.21	AUG 05	223.75	APR 16	220.60	30	216.97
25	225.31	10	223.66	AUG 24	220.20	MAY 05	216.66
31	225.01	15	223.70	SEP 10	221.20	10	216.95
NOV 05	225.00	20	223.69	15	221.02	15	216.70
10	225.04	25	223.69	20	220.98	20	216.32
15	224.83	31	223.62	25	220.83	25	216.66
20	224.40	SEP 05	223.41	30	221.02	31	216.59
25	224.76	10	223.72	OCT 05	220.94	JUN 05	216.52
30	224.53	15	223.52	10	220.80	10	216.56
DEC 05	224.54	20	223.52	15	221.11	15	216.39
10	224.33	25	223.49	20	220.89	20	216.34
15	225.09	30	223.67	25	220.87	25	216.39
20	224.62	OCT 05	223.45	31	220.79	30	216.37
25	224.84	10	223.39	NOV 05	220.85	JUL 05	216.31
31	225.14	15	223.56	10	220.98	10	216.30
JAN 05, 1969	225.12	20	223.50	DEC 05	220.78	15	216.09
10	224.86	25	223.42	10	220.93	20	216.08
15	224.85	31	223.61	15	220.65	25	216.06
20	224.82	NOV 05	223.61	20	220.86	31	216.03
25	224.86	10	223.49	25	220.43	AUG 05	215.97
31	225.07	15	223.80	31	220.44	10	215.88
FEB 05	224.86	20	223.38	JAN 05, 1974	220.24	15	215.88
10	225.07	25	223.23	10	220.36	20	215.79
15	224.80	30	223.28	15	220.84	25	215.68
20	224.64	DEC 05	223.62	20	220.32	31	215.61
25	224.63	10	223.35	25	220.33	SEP 05	215.69
28	224.70	15	223.38	31	220.38	10	215.54
MAR 05	224.70	20	223.30	FEB 05	220.15	15	215.62
10	224.79	25	223.52	10	220.50	20	215.49
15	225.02	31	223.47	15	220.25	25	215.54
20	224.86	JAN 05, 1971	223.49	20	219.84	30	215.40
25	224.95	10	223.36	25	220.38	OCT 05	215.44
31	224.68	15	223.50	28	220.13	10	215.27
APR 05	224.66	20	223.34	MAR 05	220.00	15	215.38
10	224.70	25	223.31	10	219.86	20	215.21
15	224.42	31	223.30	15	220.00	25	215.24

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OCT 31, 1975	214.91	DEC 31, 1975	214.11	SEP 26, 1979	205.54 S	APR 25, 1981	203.52 S
NOV 05	215.13	JAN 05, 1976	214.45	OCT 10	204.40 S	MAY 22	203.21 S
10	214.83	10	214.38	31	206.59 S	JUN 24	203.73 S
15	215.08	15	214.67	MAR 14, 1980	203.52	JUL 29	202.94 S
20	214.96	20	214.60	OCT 13	202.80	AUG 29	204.00 S
25	214.88	25	214.18	NOV 23	202.95 S	OCT 02	209.77 S
30	214.76	MAR 23, 1977	207.03	DEC 20	202.97 S	07	205.44 S
DEC 05	214.81	OCT 26	207.52	FEB 06, 1981	208.70 S	NOV 14	203.32 S
10	214.65	MAR 20, 1978	206.66	26	205.94 S	MAR 25, 1982	202.51 S
15	214.86	OCT 12	205.88 S	MAR 24	204.37 S	OCT 05	201.37 S
20	214.90	MAR 20, 1979	206.15 S R	26	203.94	MAR 24, 1983	200.60 S
25	214.67	AUG 28	204.48 S				

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OCT 10, 1963	310.21	FEB 28, 1965	272.08	MAR 20, 1967	240.03	JUN 30, 1968	228.02
15	306.21	MAR 05	271.94	25	239.42	JUL 05	227.78
20	303.47	10	271.57	31	239.01	SEP 10	225.90
25	301.87	15	271.24	APR 05	239.75	15	225.61
31	300.21	20	271.02	10	239.60	20	225.39
NOV 05	298.94	25	270.63	15	239.17	25	225.75
10	297.95	31	270.40	20	239.19	30	225.50
15	296.78	APR 05	270.07	25	239.14	OCT 05	225.35
20	304.06	10	269.58	30	238.31	10	225.10
25	300.91	15	269.37	MAY 05	238.42	15	224.78
DEC 05	297.64	20	269.28	10	238.30	20	224.81
10	296.22	JUN 14	261.17	15	238.49	25	224.80
15	295.25	JUL 31	265.53	20	238.38	31	224.44
20	294.18	AUG 05	265.09	25	238.09	NOV 05	224.27
25	293.25	10	264.78	31	237.72	10	224.26
31	292.25	15	264.40	JUN 05	237.66	15	224.08
JAN 05, 1964	291.38	20	265.09	10	237.37	20	224.24
10	290.54	25	265.45	15	237.17	25	223.90
15	289.92	31	264.76	20	237.18	30	223.81
20	289.13	SEP 05	264.08	25	236.17	DEC 05	223.99
25	288.45	10	263.60	30	236.23	10	224.06
31	287.70	15	263.30	JUL 05	236.19	15	223.87
FEB 05	286.98	20	262.79	10	236.02	20	223.34
10	286.68	25	262.40	15	235.89	25	223.27
15	285.82	30	262.04	20	235.70	31	223.23
20	285.23	OCT 05	261.67	25	235.66	JAN 05, 1969	223.10
25	284.46	10	261.39	31	235.50	10	222.83
29	284.02	15	260.84	AUG 05	235.32	15	222.64
MAR 05	283.40	20	260.63	10	235.12	20	222.53
10	313.45	25	260.43	15	234.84	25	222.35
15	307.45	31	260.01	20	234.76	31	222.30
20	304.05	NOV 05	259.69	25	234.61	FEB 05	222.12
25	301.80	10	259.38	31	234.58	09	222.16
31	298.57	15	259.07	SEP 05	234.35	25	221.70
APR 05	297.87	20	258.75	10	234.20	28	221.98
10	296.90	25	258.22	15	234.11	MAR 05	222.58
15	296.27	30	258.18	20	234.09	10	221.53
30	292.86	DEC 05	257.90	25	233.70	15	221.60
MAY 05	307.60	10	257.25	30	233.58	20	221.42
10	299.44	15	256.84	OCT 05	233.40	25	221.35
15	295.55	20	256.85	10	233.22	31	221.16
20	292.85	25	256.54	15	233.05	APR 05	221.09
25	293.50	31	256.12	20	233.06	10	221.00
31	291.33	JAN 05, 1966	256.03	25	232.88	15	220.82
JUN 05	289.90	10	255.82	31	232.94	20	220.94
10	294.40	15	255.46	NOV 05	232.77	25	220.84
15	291.75	20	255.12	10	232.62	30	220.66
20	289.92	25	254.90	15	232.47	MAY 05	220.55
25	288.82	31	254.49	20	232.23	10	220.60
30	287.31	FEB 05	254.32	25	231.98	JUN 05	220.05
JUL 05	286.22	10	253.82	30	231.95	10	219.77
10	285.48	15	253.70	DEC 05	231.80	15	219.81
15	284.86	20	253.52	10	231.63	20	219.76
20	283.84	25	253.18	15	231.34	25	219.50
25	283.16	28	252.95	20	231.09	30	219.38
31	282.90	MAR 05	252.77	25	231.65	JUL 05	219.44
AUG 05	281.95	10	252.55	31	231.29	10	219.46
10	281.12	15	252.17	JAN 05, 1968	231.55	15	219.42
15	280.54	20	251.95	10	231.56	20	219.36
20	279.92	25	251.69	15	231.94	25	219.20
25	279.44	31	251.53	20	231.62	31	219.14
31	278.81	APR 05	251.20	25	231.39	AUG 05	218.85
SEP 05	278.05	10	250.92	31	231.25	10	218.94
10	277.67	15	250.75	FEB 05	231.30	31	218.49
15	277.17	20	250.23	10	230.92	SEP 05	218.47
20	276.85	25	250.28	15	230.68	10	218.45
25	276.36	30	249.93	20	230.54	15	218.35
30	296.95	MAY 05	249.67	25	230.32	20	218.15
OCT 05	290.30	10	249.32	29	230.28	25	218.10
10	288.20	15	249.08	MAR 05	230.12	30	217.97
15	286.35	JUN 05	255.78	10	229.72	OCT 05	217.52
20	284.80	10	254.56	15	229.68	10	217.61
25	283.37	15	253.56	20	229.60	15	217.85
31	281.90	20	252.35	25	229.35	24	217.75
NOV 05	280.52	25	251.85	31	229.30	25	217.77
30	278.26	30	251.30	APR 05	229.42	31	217.65
DEC 05	277.50	JAN 05, 1967	244.02	10	229.45	NOV 05	217.48
10	277.22	10	243.83	15	229.12	10	217.34
14	276.81	15	243.43	20	228.87	15	217.10
22	276.35	20	243.28	25	228.95	20	217.27
25	275.38	25	243.00	30	229.12	25	217.12
31	275.07	31	242.09	MAY 05	228.54	30	217.02
JAN 05, 1965	274.75	FEB 05	242.79	10	228.67	DEC 05	216.65
10	274.30	10	242.21	20	228.44	10	216.47
15	273.95	15	241.89	25	228.04	15	216.72
20	273.40	20	241.32	31	227.99	20	216.55
FEB 08	273.38	25	241.04	JUN 05	227.60	25	216.42
10	273.16	28	240.72	10	227.65	31	216.35
15	272.97	MAR 05	240.21	15	228.09	JAN 15, 1970	216.05
20	272.74	10	240.50	20	227.80	20	216.10
25	272.37	15	240.18	25	227.66		

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JAN 25, 1970	215.91
31	215.92
FEB 05	215.75
10	215.82
15	215.63
20	215.70
25	215.67
28	215.83
MAR 05	215.15
10	214.92
15	215.18
20	215.16
25	215.01
31	214.87
APR 05	215.07
10	214.88
15	214.62
20	214.56
25	214.53
30	214.50
MAY 05	214.48
10	214.13
15	214.31
20	214.08
25	214.10
31	213.95
JUN 05	213.87
10	213.61
15	213.63
20	213.58
25	213.51
30	213.33
JUL 05	213.45
10	213.42
15	213.32
20	213.20
25	213.13
31	212.98
AUG 05	212.88
15	212.74
20	212.75
25	212.69
31	212.56
SEP 05	212.33
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OCT 05	212.30
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NOV 05	211.98
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DEC 05	211.50
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25	211.13
31	211.05
JAN 05, 1971	210.98
31	210.62
FEB 05	210.43
10	210.57
15	210.28
20	209.97
25	210.09
28	210.09
MAR 05	209.93
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15	209.92
20	209.90
25	209.68
31	209.59
APR 05	209.87
10	209.65
15	209.41
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25	209.15
30	209.33
MAY 05	208.96
10	209.07
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20	208.84
25	208.79
31	208.66
JUN 05	208.78
10	208.59
15	208.67
20	208.75
25	208.67
30	208.58
JUL 05	208.50
10	208.47
15	208.33
20	208.33
25	208.23
31	208.12
AUG 05	208.02
10	207.97
15	207.82
AUG 20, 1971	207.79
25	207.74
31	207.67
SEP 05	207.61
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30	207.13
OCT 05	207.43
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NOV 05	206.83
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DEC 05	206.45
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JAN 05, 1972	206.52
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FED 05	206.46
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MAR 05	206.16
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APR 05	205.74
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MAY 05	205.23
25	205.10
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JUN 05	205.09
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JUL 05	204.67
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15	204.43
AUG 15	205.00
20	205.00
25	204.82
SEP 15	204.75
20	204.70
25	204.52
30	204.67
OCT 05	204.54
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15	204.47
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25	204.57
31	204.48
NOV 05	204.41
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25	204.38
30	204.48
DEC 05	204.04
JAN 25, 1973	202.88
31	202.62
FEB 05	202.83
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15	202.67
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MAR 05	202.28
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APR 05	202.28
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MAY 05	202.13
MAY 10, 1973	202.22
15	202.28
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25	201.94
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JUN 05	201.96
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15	201.84
20	201.92
25	201.88
30	201.77
JUL 05	201.76
10	201.75
15	201.71
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25	201.55
31	201.53
AUG 05	201.47
10	201.35
15	201.35
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25	201.13
31	201.06
SEP 05	201.09
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25	200.71
30	200.83
OCT 05	200.77
10	200.62
15	200.80
20	200.68
25	200.60
31	200.53
NOV 05	200.41
10	200.55
15	200.40
20	200.20
25	200.15
30	200.45
DEC 05	200.40
10	200.43
15	200.22
20	200.37
25	200.05
31	199.98
JAN 05, 1974	199.78
10	199.75
15	200.14
20	199.96
25	199.93
31	199.83
FEB 05	199.72
10	199.85
15	199.67
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25	199.76
28	199.60
MAR 05	199.47
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25	199.30
31	199.12
APR 05	199.14
10	198.89
15	199.03
20	198.79
25	198.79
30	198.83
MAY 05	198.65
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15	198.32
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25	198.56
31	198.39
JUN 05	198.30
10	198.36
15	198.26
20	198.21
25	198.19
30	198.06
JUL 05	198.05
10	197.97
15	197.99
20	197.99
25	197.88
31	197.78
AUG 05	198.40 E
10	199.00 E
15	199.60 E
20	200.20 E
25	200.80 E
31	201.40 E
SEP 05	202.00 E
10	202.60 E
15	203.20 E
20	203.80 E
25	204.40 E
30	205.00 E
OCT 05	205.60 E
10	206.20 E
15	206.50 E
OCT 20, 1974	206.40
25	206.48
31	206.19
NOV 05	206.18
10	206.15
15	206.07
20	210.31 E
25	214.50 E
30	218.70 E
DEC 05	222.90 E
10	227.10 E
15	231.32 E
20	225.75
25	222.95
31	220.66
JAN 05, 1975	219.36
10	218.00 E
15	216.00 E
20	245.35
25	243.11
31	229.05
FEB 05	226.22
10	223.58
15	221.80
20	246.58
25	234.46
28	231.74
MAR 05	228.24
10	225.85
15	224.25
20	223.14
25	221.98
31	221.06
APR 05	220.47
10	238.74
15	231.43
20	228.15
25	227.90 E
30	227.65 E
MAY 05	227.40 E
10	227.15 E
15	226.90 E
20	226.65 E
25	226.40 E
31	226.15 E
JUN 05	225.90 E
10	225.65 E
15	225.40 E
20	225.15 E
25	224.90 E
30	224.65 E
JUL 05	224.40
10	223.10
15	222.02
20	221.19
25	220.54
31	219.86
AUG 05	219.38
10	218.95
15	218.60 E
20	218.30 E
25	218.00 E
31	217.64 E
SEP 05	217.34 E
10	217.04 E
15	216.74 E
20	216.44 E
25	216.14 E
30	215.84 E
OCT 05	215.54 E
10	215.24 E
15	215.00 E
20	214.74
25	214.55
31	214.20
NOV 05	214.13
10	213.79
15	213.78
20	213.56
25	213.41
30	213.09
DEC 05	213.07
10	212.82
15	212.74
20	212.70 E
25	212.80 E
31	212.80 E
JAN 05, 1976	242.12
10	242.10
15	242.12
20	242.12
25	242.12
MAR 03	241.10
OCT 07	234.98
MAR 23, 1977	224.21
OCT 26	216.41
MAR 20, 1978	214.21
OCT 12	211.43
MAR 10, 1979	207.05 S
OCT 10	205.64 S
MAR 14, 1980	203.43 S
OCT 13	200.62 S

(D-44- 3) 2BDC- 1 ALT. 3,820

APR 27, 1981	107.53 S	MAY 26, 1981	107.31 S	JUN 18, 1981	106.98 S	AUG 29, 1981	106.63 S

(D-44- 4) 8BBC- 1 ALT. 3,722.87

JUL 15, 1964	357.07	MAY 05, 1966	270.08	SEP 30, 1967	233.63	APR 15, 1969	204.05
20	355.03	10	269.11	OCT 05	233.32	20	203.88
25	354.34	15	268.30	10	233.14	25	203.42
31	353.85	20	267.81	15	233.06	30	202.69
AUG 05	353.05	25	267.31	20	232.63	MAY 05	202.15
10	352.18	31	266.35	25	232.24	10	201.62
15	351.39	JUN 05	265.69	31	232.01	15	200.80
20	350.55	10	264.99	NOV 05	231.70	20	200.14
25	349.92	15	264.31	10	231.43	25	199.16
31	348.93	20	263.67	15	231.37	31	198.00
NOV 05	337.05	25	263.04	DEC 05	230.20	JUN 05	197.70
10	336.02	30	262.57	10	230.04	10	196.33
15	335.53	JUL 05	261.97	15	229.53	15	195.52
20	335.14	10	261.59	20	229.25	20	194.94
JAN 10, 1965	331.70	15	261.10	25	229.62	25	193.67
15	331.51	20	260.60	31	229.10	30	193.06
20	330.65	25	260.19	FEB 10, 1968	227.32	JUL 05	192.39
25	329.90	31	259.71	15	227.24	10	191.90
31	329.03	AUG 05	259.24	20	226.94	15	191.20
FEB 05	328.50	10	258.72	25	226.93	20	190.65
10	327.93	15	258.55	28	226.65	25	190.06
15	327.67	20	258.00	MAR 05	226.27	31	189.55
20	327.28	25	257.70	10	225.99	AUG 05	188.68
25	326.40	31	257.25	15	226.18	10	188.63
28	325.72	SEP 05	256.95	20	226.02	15	188.45
MAR 05	325.55	10	256.48	25	225.73	20	188.25
10	324.75	15	256.13	31	225.82	25	187.67
15	324.27	20	255.95	APR 05	225.85	31	187.32
20	323.85	25	255.48	10	226.10	SEP 05	187.03
25	323.14	30	255.25	15	225.87	10	186.83
31	322.46	OCT 05	255.21	20	225.90	15	186.58
APR 05	322.14	10	254.72	25	226.02	20	186.27
10	321.37	15	254.40	30	226.05	25	186.09
15	321.23	20	254.00	MAY 05	225.89	30	186.00
20	320.57	25	254.04	10	226.02	OCT 05	185.84
25	320.00	31	253.64	15	225.89	10	185.11
30	319.55	NOV 05	253.22	20	225.87	15	184.85
MAY 05	318.80	10	252.80	25	225.85	20	184.75
10	318.50	15	252.65	31	225.22	25	184.37
15	317.93	20	252.38	JUN 05	224.57	31	183.89
20	317.38	25	252.17	10	223.97	NOV 05	183.40
25	316.77	30	251.75	15	223.07	10	183.16
31	316.31	DEC 05	250.90	20	222.27	15	182.16
JUN 05	315.94	10	251.23	25	221.48	20	182.88
10	315.37	15	251.00	30	220.82	25	182.50
15	314.32	20	250.44	JUL 05	220.08	30	182.16
20	313.80	25	250.00	10	219.46	DEC 05	181.60
25	313.07	31	249.98	15	218.67	10	181.35
30	312.26	JAN 05, 1967	249.48	20	218.44	15	181.42
JUL 05	311.36	10	250.00	25	217.95	20	181.15
10	310.33	15	249.50	31	217.35	25	180.78
15	309.54	20	249.21	AUG 05	216.86	31	180.65
20	308.46	25	248.74	10	216.52	JAN 05, 1970	180.45
25	307.80	31	248.62	15	215.75	10	180.37
31	306.55	FEB 05	248.41	20	215.22	15	180.14
AUG 05	305.53	10	248.14	25	215.03	20	180.32
10	304.23	15	248.03	31	214.57	25	180.60
15	303.92	20	248.00	SEP 05	214.24	31	180.45
20	303.17	25	247.46	10	213.82	FEB 05	180.31
25	302.53	28	247.78	15	213.33	10	180.17
31	301.79	MAR 05	247.17	20	213.14	15	180.05
SEP 05	301.44	10	247.07	25	213.26	20	179.94
10	300.29	15	247.12	30	212.90	25	179.68
15	299.45	20	246.90	OCT 05	212.57	28	179.30
20	298.84	25	246.49	10	212.37	MAR 05	178.98
25	298.10	31	246.09	15	211.97	10	178.57
30	297.76	APR 05	246.06	20	211.95	15	177.95
OCT 05	296.79	10	245.81	25	211.77	20	177.76
10	296.17	15	245.60	31	211.63	25	177.48
15	295.18	20	245.58	NOV 05	211.33	31	177.05
20	295.03	25	245.57	10	211.27	APR 05	177.17
25	294.35	30	245.48	15	210.87	10	176.92
31	293.51	MAY 05	245.37	20	211.08	15	176.87
NOV 05	292.67	10	245.19	25	210.51	20	176.82
10	292.00	15	245.57	30	210.13	25	176.85
15	291.37	20	245.41	DEC 05	210.00	30	176.99
20	290.70	25	245.21	10	209.92	MAY 05	176.92
25	289.73	31	244.62	15	209.64	10	176.63
30	289.47	JUN 05	244.38	20	209.00	15	177.06
DEC 05	289.00	10	243.57	25	209.12	20	176.13
10	287.81	15	243.04	31	209.45	25	175.63
15	286.96	20	242.54	JAN 05, 1969	209.18	31	174.64
20	286.80	25	241.88	10	208.84	JUN 05	173.75
25	285.31	30	241.17	15	208.62	10	172.48
31	283.75	JUL 05	240.49	20	208.39	15	171.60
JAN 05, 1966	283.15	10	240.04	25	208.20	20	170.82
10	282.50	15	239.40	31	208.17	25	169.95
15	281.86	20	238.78	FEB 05	207.76	30	168.97
20	280.93	25	238.24	10	207.83	JUL 05	168.26
25	280.72	31	237.75	15	207.28	10	167.57
FEB 25	278.35	AUG 05	237.25	20	207.07	15	166.53
28	278.13	10	237.03	25	206.65	20	165.82
MAR 05	277.54	15	236.41	28	206.56	25	165.15
10	276.73	20	235.99	MAR 05	206.28	31	164.27
15	276.00	25	235.88	10	206.07	AUG 05	163.82
20	275.39	31	235.50	15	206.06	10	163.35
25	274.92	SEP 05	235.19	20	205.61	15	162.92
31	274.29	10	234.82	25	205.57	20	162.78
APR 05	273.69	15	234.54	31	204.96	25	162.61
10	272.63	20	234.29	APR 05	204.71	31	162.25
15	272.47	25	233.95	10	204.60	SEP 05	161.91

(D-44- 4) 8BBC- 1 -- CONTINUED

SEP 10, 1970	161.62	MAR 20, 1972	133.68	JUL 31, 1973	115.97	JAN 05, 1975	91.17
15	161.31	25	133.34	AUG 05	115.38	10	90.93
OCT 25	158.21	31	133.15	10	114.65	15	91.58
31	157.83	APR 05	132.90	15	114.12	20	91.48
NOV 05	157.48	10	132.64	20	113.50	25	91.52
10	156.98	15	132.64	25	112.63	31	91.64
15	156.90	20	132.38	31	111.98	FEB 05	91.65
20	156.26	25	132.20	SEP 05	111.71	10	91.70
25	155.63	30	132.56	10	111.32	15	91.75
30	155.38	MAY 05	132.27	15	110.66	20	91.80
DEC 05	155.45	10	132.23	20	110.16	25	91.83
10	154.88	15	132.26	25	109.68	28	91.96
15	154.70	20	132.11	30	109.42	MAR 05	91.68
20	154.30	25	131.95	OCT 05	109.00	10	91.44
25	154.32	31	131.79	10	108.50	15	91.63
31	153.98	JUN 05	131.52	15	108.01	20	91.64
JAN 05, 1971	153.90	10	130.98	20	107.24	25	91.26
10	153.63	15	130.70	25	106.32	31	91.44
15	153.77	20	130.17	31	106.29	APR 05	91.52
20	153.23	25	129.70	NOV 05	106.08	10	91.57
25	153.10	30	129.56	10	105.86	15	91.48
31	152.57	JUL 05	129.22	15	105.43	20	91.62
FEB 05	152.15	10	128.79	20	104.88	25	91.50
10	152.08	15	128.58	DEC 05	104.02	30	91.30
15	151.50	20	128.31	10	103.79	MAY 05	91.10
20	150.88	25	128.39	15	103.53	10	90.99
25	150.75	31	128.46	20	103.26	15	90.64
28	150.67	AUG 05	128.48	25	102.46	20	90.06
MAR 05	150.32	10	128.55	31	102.06	25	89.84
10	150.23	15	128.90	JAN 05, 1974	101.75	31	89.27
15	150.19	20	129.08	10	101.76	JUN 05	88.40
20	149.81	25	129.09	15	102.02	10	87.97
25	149.43	31	129.35	20	101.41	15	87.13
31	149.07	SEP 05	129.54	25	101.31	20	86.31
APR 05	149.28	10	129.80	31	101.20	25	85.44
10	148.95	15	130.11	FEB 05	100.77	30	84.43
15	148.58	20	130.38	10	100.90	JUL 05	83.42
20	148.31	25	130.42	15	100.55	10	82.48
25	147.94	30	130.90	20	99.91	15	81.33
30	148.09	OCT 05	131.04	25	100.09	20	80.53
MAY 05	147.58	10	131.03	28	99.82	25	79.79
10	147.54	15	131.18	MAR 05	99.46	31	79.14
15	147.12	20	130.70	10	99.30	AUG 05	78.55
20	146.53	25	130.60	15	99.03	10	78.26
25	146.27	31	130.38	20	98.55	15	78.15
31	145.88	NOV 05	130.01	25	98.32	20	77.96
JUN 05	145.32	10	129.78	31	97.82	25	77.30
10	144.68	15	129.63	APR 05	97.86	31	76.98
15	144.41	20	129.49	10	97.46	SEP 05	76.98
20	143.60	25	129.58	15	97.71	10	76.75
25	142.77	30	129.58	20	97.38	15	76.79
30	141.85	DEC 05	128.87	25	97.31	20	76.64
JUL 05	141.05	10	129.17	30	97.17	25	76.74
10	140.83	15	129.60	MAY 05	96.58	30	76.71
15	139.81	20	129.41	10	96.24	OCT 05	76.89
20	139.32	25	129.58	15	95.86	10	76.95
25	138.75	31	129.40	20	95.69	15	77.19
31	138.60	JAN 05, 1973	129.53	25	95.11	20	77.10
AUG 05	138.51	10	129.65	JUN 10	92.82	25	77.22
10	138.09	15	130.08	15	92.08	31	76.82
15	138.11	20	129.82	20	91.41	NOV 05	76.85
20	137.90	25	130.52	25	90.93	10	76.35
25	137.82	31	130.13	JUL 05	89.83	15	76.45
31	137.31	FEB 05	130.75	10	89.55	20	76.24
SEP 05	137.45	10	130.68	15	89.51	25	76.03
10	137.23	15	130.96	20	89.45	30	76.01
15	137.31	20	131.25	25	89.25	DEC 05	75.78
20	136.92	25	131.22	31	89.17	10	75.42
OCT 20	136.22	28	131.03	AUG 05	89.14	15	75.57
25	135.78	MAR 05	130.88	10	89.27	20	75.46
31	135.65	10	130.98	15	89.36	25	75.17
NOV 05	135.55	15	131.11	20	89.38	31	74.46
10	135.68	20	130.85	25	89.72	JAN 05, 1976	74.68
15	135.10	25	131.35	31	90.00	10	74.61
20	135.34	31	131.50	SEP 05	90.29	15	74.77
25	135.23	APR 05	131.87	10	90.44	20	74.78
30	134.93	10	132.22	15	90.48	25	74.35
DEC 05	135.08	15	132.43	20	90.34	31	74.61
10	134.94	20	132.77	25	90.46	FEB 05	74.13
15	134.90	25	133.34	30	90.71	10	74.29
20	135.22	30	133.22	OCT 05	90.55	MAR 03	74.14
25	135.09	MAY 05	133.11	10	90.68	OCT 07	72.58
31	135.27	10	133.11	15	90.94	MAR 23, 1977	79.26
JAN 05, 1972	135.46	15	133.28	20	90.77	OCT 26	86.87
10	135.23	20	132.52	25	90.99	MAR 20, 1978	95.66
15	135.54	25	131.25	31	90.76	OCT 12	85.58
20	135.26	31	129.86	NOV 05	90.78	MAR 20, 1979	91.25 S
25	135.23	JUN 05	129.00	10	90.86	JUL 24	64.48 S
31	135.25	10	127.48	15	90.66	OCT 10	61.04 S
FEB 05	135.17	15	126.06	20	90.90	OCT 31	60.75 S
10	135.27	20	124.77	25	90.78	MAR 14, 1980	59.55
15	135.06	25	123.20	30	90.86	OCT 13	47.57
20	135.11	30	121.63	DEC 05	90.72	MAR 26, 1981	55.14
25	134.84	JUL 05	120.59	10	90.77	OCT 07	54.34
29	134.63	10	119.82	15	90.82	MAR 26, 1982	59.73
MAR 05	134.67	15	118.77	20	90.92	OCT 05	44.82
10	134.40	20	117.88	25	90.91	MAR 23, 1983	45.04
15	134.14	25	117.06	31	91.07		

(D-44- 4) 8BBD- 1 ALT. 3,760

JUL 24, 1979	73.32 S	DEC 21, 1980	61.48 S	APR 25, 1981	63.60 S	AUG 25, 1981	63.90 S
AUG 28	70.35 S	JAN 24, 1981	61.95 S	MAY 22	63.41 S	26	63.96 S
SEP 29	70.61 S	FEB 26	62.83 S	JUN 24	63.24 S	29	64.27 S
OCT 31	70.47 S	MAR 24	63.17 S	JUL 29	63.22 S	OCT 02	65.82 S
						NOV 14	66.39 S

WELLS IN ARIZONA

(A-41- 8)14BCB- 1 ALT. 4,120

OCT 00, 1957	880	R	JAN 24, 1981	496	S	FEB 09, 1981	492.99	S	APR 13, 1983	484.70	S
SEP 26, 1979	510	T									

(A-41- 8)23DAC- 1 ALT. 3,917

SEP 30, 1964	721	R	SEP 30, 1969	620	R	APR 18, 1974	497	R	NOV 17, 1978	415	R
OCT 26	720	R	NOV 05	617	R	MAY 15	495	R	DEC 15	414	R
NOV 30	719	R	DEC 04	615	R	JUN 13	494	R	JAN 18, 1979	413	R
DEC 28	718	R	23	614	R	JUL 17	491	R	FEB 15	413	R
JAN 25, 1965	717	R	JAN 15, 1970	612	R	AUG 16	489	R	MAR 15	413	R
FEB 23	716	R	FEB 20	609	R	SEP 18	479	R	APR 16	413	R
MAR 29	716	R	MAR 24	606	R	OCT 17	477	R	MAY 16	411	R
APR 28	716	R	APR 30	604	R	NOV 14	475	R	JUN 14	411	R
MAY 17	715	R	MAY 28	601	R	DEC 18	473	R	JUL 13	410	R
JUN 15	714	R	JUN 26	598	R	JAN 15, 1975	471	R	AUG 15	409	R
JUL 12	713	R	JUL 29	596	R	FEB 19	469	R	SEP 19	407	R
AUG 09	712	R	AUG 25	593	R	MAR 19	467	R	OCT 17	406	R
SEP 20	711	R	OCT 01	590	R	APR 16	465	R	NOV 16	406	R
OCT 18	710	R	28	587	R	MAY 14	464	R	DEC 14	405	R
NOV 16	709	R	NOV 23	584	R	JUN 11	460	R	JAN 15, 1980	403	R
DEC 13	708	R	DEC 29	580	R	JUL 16	460	R	FEB 15	402	R
JAN 12, 1966	708	R	JAN 22, 1971	577	R	AUG 13	458	R	MAR 14	400	R
FEB 07	706	R	FEB 23	574	R	SEP 18	455	R	APR 16	400	R
MAR 09	706	R	MAR 25	571	R	OCT 15	454	R	MAY 14	398	R
APR 15	705	R	APR 27	568	R	NOV 19	452	R	JUN 17	397	R
MAY 16	703	R	MAY 27	565	R	DEC 17	450	R	JUL 17	396	R
JUN 13	703	R	JUN 29	562	R	JAN 14, 1976	449	R	AUG 13	393	R
JUL 08	701	R	JUL 27	559	R	FEB 11	448	R	SEP 22	392	R
AUG 10	700	R	AUG 27	557	R	MAR 31	444	R	OCT 15	390	R
SEP 07	699	R	SEP 30	564	R	APR 14	443	R	NOV 13	389	R
OCT 17	698	R	OCT 22	562	R	MAY 20	441	R	DEC 16	388	R
NOV 17	696	R	NOV 18	560	R	JUN 16	441	R	JAN 15, 1981	387	R
DEC 12	695	R	DEC 23	557	R	JUL 22	438	R	FEB 13	386	R
JAN 09, 1967	694	R	JAN 19, 1972	553	R	AUG 17	436	R	MAR 16	385	R
MAR 08	690	R	FEB 17	552	R	SEP 15	433	R	APR 15	384	R
APR 11	688	R	MAR 16	549	R	OCT 13	433	R	MAY 15	382	R
MAY 15	687	R	APR 18	546	R	NOV 22	431	R	JUN 15	382	R
JUN 15	684	R	MAY 17	543	R	DEC 15	430	R	JUL 15	381	R
JUL 10	682	R	JUN 15	541	R	JAN 21, 1977	428	R	AUG 14	380	R
AUG 09	680	R	JUL 21	538	R	FEB 17	430	R	28	378.1	L
SEP 19	677	R	AUG 15	536	R	MAR 16	426	R	SEP 15	379	R
OCT 06	676	R	SEP 21	534	R	APR 13	425	R	OCT 15	379	R
NOV 07	674	R	OCT 18	532	R	MAY 18	424	R	NOV 16	379	R
29	673	R	NOV 15	530	R	JUN 16	423	R	DEC 16	378	R
JAN 03, 1968	669	R	DEC 15	528	R	JUL 14	422	R	JAN 18, 1982	378	R
29	667	R	JAN 19, 1973	525	R	AUG 16	421	R	FEB 16	382	R
FEB 26	665	R	FEB 13	524	R	SEP 19	420	R	MAR 16	377	R
MAR 28	663	R	MAR 14	522	R	OCT 19	420	R	APR 15	375	R
APR 30	660	R	APR 18	520	R	NOV 16	419	R	MAY 14	375	R
JUN 12	658	R	MAY 16	519	R	DEC 13	419	R	JUN 15	376	R
NOV 01	652	R	JUN 15	517	R	JAN 17, 1978	418	R	JUL 15	375	R
DEC 27	642	R	JUL 18	515	R	FEB 15	418	R	AUG 13	375	R
JAN 27, 1969	639	R	AUG 16	513	R	MAR 09	417	R	SEP 17	374	R
FEB 27	638	R	SEP 19	511	R	APR 13	417	R	OCT 15	374	R
MAR 27	635	R	OCT 16	510	R	MAY 19	417	R	NOV 17	372	R
APR 21	633	R	NOV 14	508	R	JUN 14	417	R	DEC 15	372	R
MAY 27	630	R	DEC 14	506	R	JUL 12	416	R	JAN 14, 1983	371	R
JUL 01	627	R	JAN 16, 1974	505	R	AUG 16	415	R	FEB 16	370	R
17	626	R	FEB 13	502	R	SEP 14	415	R	MAR 15	370	R
AUG 22	623	R	MAR 13	500	R	OCT 17	414	R			

(A-42- 8)32CDD- 1 ALT. 4,100

OCT 15, 1972	604	R	SEP 26, 1973	553	R	JUL 22, 1976	543	R	JUN 10, 1981	510	R
OCT 21	582	R									

(A-42- 8)35DAB- 1 ALT. 3,736

JUL 00, 1958	395	R	OCT 31, 1979	73.43	S	JUN 24, 1981	67.54	S	OCT 02, 1981	70.52	S
AUG 07, 1979	73.10	S	MAR 24, 1981	66.80	S	JUL 29	68.92	S	NOV 14	71.10	S
29	72.20	S	APR 25	67.11	S	AUG 25	68.45	S			
SEP 26	73.15	S	MAY 22	67.18	S	29	68.75	S			

Table 13.--Water levels in selected observation wells--Continued

(A-42- 8)36CBC- 1 ALT. 3,735

JUL 02, 1964	388	R
AUG 03	370	R
SEP 08	359	R
OCT 05	353	R
NOV 02	347	R
DEC 07	341	R
JAN 04, 1965	337	R
FEB 01	333	R
MAR 01	329	R
APR 05	325	R
MAY 03	322	R
JUN 01	319	R
JUL 12	311	R
AUG 09	304	R
SEP 07	299	R
OCT 04	295	R
NOV 01	291	R
DEC 13	284	R
JAN 12, 1966	280	R
FEB 07	277	R
MAR 09	274	R
APR 06	271	R
MAY 02	268	R
JUL 08	259	R
AUG 10	256	R
SEP 07	255	R
OCT 03	254	R
31	253	R
DEC 12	252	R
JAN 09, 1967	251	R
FEB 07	251	R
MAR 08	250	R
APR 11	250	R
MAY 01	250	R
JUN 02	250	R
JUL 10	246	R
AUG 09	242	R
28	241	R
OCT 06	239	R
NOV 07	238	R
29	237	R
JAN 03, 1968	236	R
29	235	R
FEB 26	235	R
MAR 27	234	R
APR 30	235	R
JUN 12	234	R
OCT 31	218	R
DEC 27	216	R
JAN 27, 1969	215	R
FEB 27	214	R
MAR 27	213	R
APR 21	212	R
MAY 23	206	R
JUL 01	196	R
17	193	R
AUG 22	189	R
SEP 30	189	R
NOV 05	186	R
DEC 04, 1969	184	R
23	184	R
JAN 15, 1970	184	R
FEB 20	184	R
MAR 24	182	R
APR 30	183	R
MAY 28	181	R
JUN 26	172	R
JUL 29	164	R
AUG 24	163	R
25	163	R
OCT 01	161	R
29	159	R
NOV 23	157	R
DEC 29	155	R
JAN 22, 1971	156	R
FEB 23	153	R
MAR 25	152	R
APR 27	151	R
MAY 27	149	R
JUN 29	141	R
JUL 27	139	R
SEP 30	139	R
OCT 22	139	R
NOV 18	138	R
DEC 23	140	R
JAN 19, 1972	140	R
FEB 17	141	R
MAR 16	139	R
APR 18	137	R
MAY 17	138	R
JUN 15	136	R
JUL 21	133	R
AUG 15	135	R
SEP 21	139	R
OCT 18	140	R
NOV 15	138	R
DEC 15	138	R
JAN 19, 1973	139	R
FEB 13	141	R
MAR 14	142	R
APR 18	143	R
MAY 16	146	R
JUN 15	133	R
JUL 18	120	R
AUG 16	115	R
SEP 19	112	R
OCT 16	109	R
NOV 14	107	R
DEC 14	105	R
JAN 16, 1974	104	R
FEB 13	103	R
MAR 13	102	R
APR 18	102	R
MAY 15	99	R
JUN 13	93	R
JUL 17	90	R
AUG 16	93	R
SEP 18	96	R
OCT 17, 1974	97	R
NOV 14	97	R
DEC 18	97	R
JAN 15, 1975	99	R
FEB 19	100	R
MAR 19	100	R
APR 16	99	R
MAY 14	99	R
JUN 11	93	R
JUL 16	83	R
AUG 13	81	R
SEP 18	81	R
OCT 15	83	R
NOV 19	83	R
DEC 17	80	R
JAN 14, 1976	84	R
FEB 11	85	R
MAR 31	82	R
APR 14	82	R
MAY 20	86	R
JUN 23	83	R
JUL 22	82	R
AUG 17	82	R
SEP 15	84	R
OCT 13	81	R
NOV 22	84	R
DEC 15	86	R
JAN 21, 1977	88	R
FEB 17	90	R
MAR 16	91	R
APR 13	92	R
MAY 18	90	R
JUN 16	89	R
JUL 14	87	R
AUG 16	84	R
SEP 19	100	R
OCT 17	102	R
NOV 16	103	R
DEC 13	105	R
JAN 17, 1978	108	R
FEB 15	111	R
MAR 09	113	R
APR 13	114	R
MAY 19	112	R
JUN 14	105	R
JUL 12	96	R
AUG 16	95	R
SEP 14	97	R
OCT 17	99	R
NOV 17	102	R
DEC 15	104	R
JAN 18, 1979	107	R
FEB 15	109	R
MAR 15	109	R
APR 16	99	R
MAY 16	95	R
JUN 14	86	R
JUL 13	71	R
AUG 07	67.82	S
AUG 15, 1979	68	R
28	67.44	S
SEP 19	69	R
26	68.77	S
OCT 17	69	R
NOV 16	70	R
DEC 14	71	R
JAN 15, 1980	71	R
FEB 15	71	R
MAR 14	69	R
APR 16	69	R
MAY 14	65	R
JUN 17	55	R
JUL 17	40	R
AUG 13	53	R
SEP 22	55	R
OCT 15	58	R
NOV 13	58	R
DEC 16	62	R
21	61.18	S
JAN 15, 1981	62	R
24	62.00	S
FEB 13	63	R
26	63.40	S
MAR 16	63	R
24	63.59	S
APR 15	64	R
25	63.92	S
MAY 15	64.00	R
22	63.97	S
JUN 15	63	R
24	63.95	S
JUL 15	62	R
29	62.80	S
AUG 14	65	R
24	65.47	S
29	66.00	S
SEP 15	67	R
OCT 02	67.84	S
15	68	R
NOV 14	68.37	S
16	71	R
DEC 16	69	R
JAN 18, 1982	72	R
FEB 16	75	R
MAR 16	75	R
APR 15	75	R
MAY 14	72	R
JUN 15	65	R
JUL 15	58	R
AUG 13	56	R
SEP 17	56	R
OCT 15	55	R
NOV 17	55	R
DEC 15	56	R
JAN 14, 1983	57	R
FEB 16	58	R
MAR 16	58	R

[Abbreviations used in column headings are as follows: UMHOS, micromhos per centimeter

Station number or name: See "Numbering system for hydrogeologic-data sites", p. 5, and figure 2.
Site: GW, ground water; LK, lake; SP, spring; SW, stream.
Geologic unit: 220NVJO, Navajo Sandstone; 220GLNC, Glen Canyon Group; 221ENRD, Entrada Sandstone.

STATION NUMBER OR NAME	SITE	GEO-LOGIC UNIT	DATE OF SAMPLE	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (UNITS)	TEMPER-ATURE (DEG C)	ALKA-LINITY FIELD (MG/L AS CACO3)	HARD-NESS (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)
(C-41- 3) 4BCA- 1	GW	220NVJO	81-06-12	415	7.6	12.5	--	220	39
(C-43- 1) 3BAC- 1	GW	220NVJO	81-02-25	1520	7.1	16.5	--	390	91
(D-33- 4)35BBD- 1	GW	220NVJO	81-04-23	415	7.2	11.5	--	200	62
36ABB- 1	GW	220NVJO	81-09-01	640	7.4	12.5	--	310	59
(D-33- 5)31ADC- 1	GW	220NVJO	81-09-01	310	8.2	17.0	--	150	37
(D-34- 4) 1CAD- 1	GW	220NVJO	81-09-01	430	7.4	12.5	--	210	52
(D-35- 3) 8ABA- 1	GW	221ENRD	81-09-03	810	7.5	13.5	--	320	81
(D-43- 1) 2BDD- 1	GW	220NVJO	79-09-26	960	7.6	16.0	120	440	98
(D-43- 2)13DCD- 1	GW	221ENRD	81-06-18	600	8.8	20.0	--	11	2.7
(A-39- 4) 6CBB- 1	GW	220GLNC	76-08-05	500	7.6	12.0	196	260	63
(A-40- 5)12DDB- 1	GW	220NVJO	76-08-05	250	8.2	12.0	87	100	22
33CBC- 1	GW	220NVJO	76-08-05	300	8.0	--	115	130	29
(A-41- 4)28ADA- 1	GW	220GLNC	76-08-06	275	7.7	16.0	152	180	43
(A-41- 8) 4DDA- 1	GW	220NVJO	74-03-03[1]	1060	7.7	--	266	7	1.0
			77-10-18	1150	7.2	24.0	250	390	81
			81-08-31	1160	7.3	23.0	--	350	75
14BCA- 1	GW	220NVJO	77-10-19	1100	7.7	--	230	400	83
			81-04-02	--	--	--	--	380	84
14BCB- 1	GW	220NVJO	58-03-10[2]	--	--	--	253	440	97
23DAC- 1	GW	220NVJO	58-03-10[2]	--	--	--	127	170	39
			81-08-29	185	9.1	20.0	--	64	7.6
23DCD- 1	GW	220NVJO	58-03-10[2]	--	--	--	120	160	36
			81-08-28	295	7.9	20.5	--	120	29
(A-42- 8)32CDD- 1	GW	220NVJO	73-03-23[1]	950	7.7	--	212	420	93
			73-08-15[1]	1000	7.4	--	230	450	118
			77-09-09[1]	--	--	--	--	--	--
			77-09-09[1]	1190	--	--	250	460	105
			81-06-11	1350	7.0	23.0	--	460	96
35DAB- 1	GW	220NVJO	58-08-20[3]	--	--	--	381	450	112
35DAB- 2	GW	220NVJO	58-12-04[1]	1370	8.3	--	407	450	110
			72-04-27[2]	1540	7.9	--	276	500	124
			77-04-05[2]	1610	7.4	--	292	460	118
			77-09-13[2]	1790	--	--	286	540	138
			77-10-18	2000	7.3	24.0	300	490	120
			77-12-05[1]	1800	--	24.0	--	--	--
			81-04-22	1280	7.0	22.5	--	480	120
35DAD- 1	GW	220NVJO	58-08-20[3]	--	7.3	--	381	470	119
35DCD- 1	GW	220NVJO	76-11-00[2]	1430	7.6	--	224	420	99
			77-09-13[2]	1610	7.5	--	281	540	133
			77-10-18	1600	7.3	24.0	300	550	130
			77-12-05[1]	1650	--	21.0	--	--	--
36CBC- 1	GW	220NVJO	58-08-20[3]	--	--	--	332	620	156
36CCC- 1	GW	220NVJO	58-12-05[1]	2050	7.8	20.0	361	560	140
36CCC- 2	GW	220NVJO	68-05-22[1]	--	7.5	--	189	330	81
			72-04-27[2]	830	8.3	--	154	330	78
			76-11-00[2]	880	8.0	--	116	250	54
			77-04-05[2]	880	7.6	--	152	270	66
			77-09-13[2]	990	7.1	--	144	300	71
			77-10-18	950	7.5	21.0	160	290	67
			77-12-05[1]	1000	--	21.0	--	--	--
(C-40- 1)23BBA-S1	SP	220NVJO	79-09-25	280	7.5	16.0	110	130	32
ESCALANTE R AB MAMIE CR AT (D-35- 4) 7BDD	SW	--	81-10-21	850	8.4	5.5	--	300	64
ESCALANTE R AB BOULDER CR AT (D-35- 5)22BBB	SW	--	81-10-21	680	8.5	12.5	--	280	64
BOULDER CREEK AT MOUTH AT (D-35- 5)22BBB	SW	--	81-10-21	280	8.6	10.0	--	130	35
ESCALANTE R AB TRIB AT (D-37- 7) 6DCD	SW	--	81-10-22	510	8.5	13.5	--	220	53
PARIA R AB SHEEP CR AT (C-39- 2)17BDB	SW	--	81-10-23	2000	8.3	5.0	--	710	150
PARIA R AB DEER CR AT (C-40- 2) 4AAB	SW	--	81-10-23	1730	8.4	8.0	--	640	130
PARIA R 3 MI SO HY 89 AT (C-43- 1)15AAC	SW	--	81-10-23	1800	8.4	18.0	--	670	140
PARIA R AB KAIBAB GULCH AT (C-44- 1)12CCA	SW	--	81-10-23	1750	--	7.5	--	670	140
LAKE POWELL AT (A-42- 8)36CAB	LK	--	77-10-18[1]	800	8.5	24.0	120	280	68
COLORADO R AT LEES FERRY, AZ	SW	--	77-01-04	815	8.0	8.0	131	270	67
			77-01-18	--	--	9.0	--	--	--
			77-02-03	820	8.3	9.0	131	280	69
			77-02-17	--	--	8.0	--	--	--
			77-03-03	880	7.5	9.0	140	300	75
			77-03-16	--	--	8.0	--	--	--
			77-04-04	940	8.0	11.0	140	300	74
			77-04-20	--	--	15.0	--	--	--
			77-05-03	940	8.0	12.0	139	310	79
			77-05-20	--	--	11.0	--	--	--
			77-06-01	945	8.0	11.0	140	300	74
			77-06-15	--	--	11.0	--	--	--
			77-07-05	890	7.9	11.0	130	290	74
			77-07-20	--	--	10.0	--	--	--
			77-08-09	950	7.9	10.0	140	300	74
			77-09-07	905	7.9	10.0	130	290	73
			77-09-12	--	--	9.5	--	--	--
			77-10-06	890	7.6	9.0	130	270	65
			77-11-04	845	7.6	9.0	130	280	71
			77-12-07	870	7.8	8.0	140	310	81

1. From files of U.S. Geological Survey, source of data unknown.
2. Analysis by Arizona State Department of Health.
3. Analysis by Arizona Testing Laboratories, Phoenix, Arizona.

MAGNESIUM DISSOLVED (MG/L AS MG)	SODIUM DISSOLVED (MG/L AS NA)	POTASSIUM DISSOLVED (MG/L AS K)	BICARBONATE FET-FLD (MG/L AS HCO3)	ALKALINITY LAB (MG/L AS CACO3)	CARBON DIOXIDE DISSOLVED (MG/L AS CO2)	SULFATE DISSOLVED (MG/L AS SO4)	CHLORIDE DISSOLVED (MG/L AS CL)	FLUORIDE DISSOLVED (MG/L AS F)	SILICA DISSOLVED (MG/L AS SIO2)	SOLIDS RESIDUE AT 180 DEG. C DISSOLVED (MG/L)	SOLIDS SUM OF CONSTITUENTS DISSOLVED (MG/L)	NITROGEN NITRATE DISSOLVED (MG/L AS N)	NITROGEN NO2+NO3 DISSOLVED (MG/L AS N)
29	6.4	1.8	--	150	8.2	28	4.1	0.0	8.1	--	210	--	10.0
38	190	7.1	--	120	21	590	33	1.0	9.2	--	1000	--	.09
11	6.2	2.8	--	190	23	11	6.1	.2	23	--	240	--	.61
40	18	7.3	--	310	24	19	7.5	.6	32	--	370	--	1.9
14	6.9	4.4	--	140	1.7	7.0	4.1	.6	27	--	190	--	.06
19	9.4	3.4	--	190	15	21	15	.5	30	--	260	--	.54
27	55	3.9	--	200	12	200	17	.5	13	--	520	--	.67
46	36	4.3	--	--	5.8	380	11	.2	9.5	704	660	--	.59
1.1	140	1.4	--	260	.8	68	7.5	.3	10	--	390	--	.11
24	12	2.6	239	--	9.5	42	26	.1	10	294	300	--	4.0
11	6.4	1.6	106	--	1.1	13	8.8	.1	9.2	126	120	--	3.0
13	14	2.0	140	--	2.2	19	15	.1	10	165	170	--	2.5
17	7.1	2.0	185	--	5.9	14	14	.1	10	205	200	--	3.6
1.0	264	--	324	--	10	170	95	.6	--	--	630	--	--
45	110	14	300	--	30	250	91	.5	13	--	750	--	.98
38	110	13	--	220	24	250	82	.5	12	--	710	--	.55
46	90	9.2	280	--	8.9	250	92	.3	13	--	720	--	.65
42	95	11	--	220	--	250	89	.3	12	--	720	--	.60
48	--	--	308	--	--	260	88	.3	--	--	790	.68	--
18	--	--	155	--	--	70	7.0	.0	--	--	230	1.10	--
11	11	3.3	--	41	.1	<5.0	34	.0	.3	--	97	--	.05
18	--	--	146	--	--	66	7.0	.1	--	--	220	1.20	--
12	2.1	3.5	--	82	2.0	18	20	.4	11	--	150	--	1.3
45	76	--	258	--	8.2	260	84	.3	--	--	660	.23	--
38	90	--	280	--	18	188	98	.3	--	--	600	--	--
--	--	--	--	--	--	--	--	--	--	--	--	.45	--
48	109	--	305	--	--	272	124	.2	--	903	--	--	--
53	120	7.3	--	270	52	280	130	.2	12	--	860	--	.38
42	--	--	464	--	--	254	140	--	17	--	1200	--	--
42	--	--	480	--	3.8	160	130	.5	18	--	830	--	--
46	217	--	336	--	6.7	455	150	.5	--	--	910	--	--
39	218	--	356	--	23	470	119	.5	--	1118	--	.68	--
48	220	--	349	--	--	520	137	.6	--	1324	--	.45	--
47	270	21	360	--	29	570	140	.7	17	1360	1400	--	.63
--	--	--	--	--	--	--	--	--	--	--	--	--	--
44	210	18	--	230	50	520	150	.7	16	--	1200	--	.64
42	--	--	464	--	37	300	152	--	18	--	1300	--	--
42	162	--	273	--	11	455	140	.4	--	1000	--	.68	--
50	162	--	343	--	17	440	106	.5	--	1211	--	.90	--
54	150	20	370	--	29	450	110	.5	16	--	1100	--	.99
--	--	--	--	--	--	--	--	--	--	--	--	--	--
55	--	--	405	--	--	800	188	--	8.0	--	2000	--	--
51	--	--	440	--	11	540	160	.5	16	--	1400	--	--
32	150	13	230	--	12	340	81	.8	15	842	830	--	--
32	94	--	188	--	1.5	225	62	.7	--	--	530	--	--
29	88	--	142	--	2.3	210	60	.7	--	584	--	--	--
26	99	--	185	--	7.4	250	54	.7	--	604	--	.90	--
30	95	--	176	--	22	276	54	.8	--	688	--	.68	--
31	97	11	190	--	9.5	270	59	.8	14	--	640	--	.64
--	--	--	--	--	--	--	--	--	--	--	--	--	--
12	3.4	3.0	--	--	6.7	23	5.2	.2	12	162	160	--	.18
34	59	3.1	--	220	1.7	120	48	.3	20	--	480	--	.54
28	42	3.2	--	170	1.0	130	45	.3	20	--	440	--	.24
11	6.1	1.9	--	120	.6	15	4.4	.1	26	--	170	--	.09
20	24	2.8	--	150	.9	84	22	.2	21	--	320	--	.16
82	160	5.8	--	190	1.8	770	27	.3	11	--	1300	--	.63
75	140	5.6	--	180	1.4	690	23	.3	11	--	1200	--	.57
78	150	6.3	--	150	1.1	800	26	.3	12	--	1300	--	.53
76	150	6.0	--	130	--	780	34	.3	11	--	1300	--	.53
26	70	4.0	150	--	.8	240	50	.3	7.5	543	540	--	.15
25	72	3.5	160	--	2.6	230	53	.3	7.4	548	540	--	.55
--	--	--	--	--	--	--	--	--	--	--	--	--	--
25	71	3.7	160	--	1.3	210	58	.3	7.6	541	530	--	.46
--	--	--	--	--	--	--	--	--	--	--	--	--	--
27	81	3.6	168	--	8.5	230	65	.3	8.0	623	580	--	.61
--	--	--	--	--	--	--	--	--	--	--	--	--	--
29	89	3.9	170	--	2.7	250	62	.3	7.3	635	600	--	.53
--	--	--	--	--	--	--	--	--	--	--	--	--	--
28	86	4.0	170	--	2.7	260	62	.3	8.1	633	610	--	.58
--	--	--	--	--	--	--	--	--	--	--	--	--	--
27	82	4.0	170	--	2.7	250	62	.2	6.6	613	590	--	.55
--	--	--	--	--	--	--	--	--	--	--	--	--	--
26	82	3.6	160	--	3.2	250	60	.3	8.0	602	580	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--
29	88	3.6	170	--	3.4	250	61	.3	8.2	614	600	--	.65
25	72	3.6	160	--	3.2	240	47	.4	8.3	575	550	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--	--
25	73	3.5	160	--	6.4	230	49	.3	8.0	543	530	--	--
24	77	3.6	160	--	6.4	230	52	.3	8.1	566	550	--	--
27	76	3.8	170	--	4.3	260	52	.1	8.2	590	590	--	--

Table 15.--Water levels of Lake Powell at Glen Canyon Dam, 1963-82
[Water levels are in feet above sea level.]

DATE	WATER LEVEL	DATE	WATER LEVEL	DATE	WATER LEVEL	DATE	WATER LEVEL
MAR 31, 1963	3233.40	APR 30, 1968	3514.04	MAY 31, 1973	3616.52	JUN 30, 1978	3649.65
APR 30	3282.20	MAY 31	3522.24	JUN 30	3636.36	JUL 31	3652.29
MAY 31	3342.50	JUN 30	3547.00	JUL 31	3644.05	AUG 31	3645.80
JUN 30	3370.50	JUL 31	3546.10	AUG 31	3645.25	SEP 30	3640.17
JUL 31	3372.20	AUG 31	3548.73	SEP 30	3646.02	OCT 31	3637.28
AUG 31	3382.40	SEP 30	3545.35	OCT 31	3645.80	NOV 30	3636.08
SEP 30	3393.60	OCT 31	3543.39	NOV 30	3646.85	DEC 31	3632.83
OCT 31	3397.83	NOV 30	3541.67	DEC 31	3648.84	JAN 31, 1979	3628.84
NOV 30	3404.73	DEC 31	3539.29	JAN 31, 1974	3647.09	FEB 28	3627.99
DEC 31	3409.73	JAN 31, 1969	3540.22	FEB 28	3648.49	MAR 31	3635.03
JAN 31, 1964	3414.60	FEB 28	3542.87	MAR 31	3651.14	APR 30	3646.28
FEB 28	3414.80	MAR 31	3543.65	APR 30	3652.34	MAY 31	3663.76
MAR 31	3410.20	APR 30	3552.61	MAY 31	3662.30	JUN 30	3680.40
APR 30	3397.70	MAY 31	3571.49	JUN 30	3667.35	JUL 31	3684.32
MAY 31	3436.10	JUN 30	3579.95	JUL 31	3662.62	AUG 31	3680.79
JUN 30	3472.48	JUL 31	3580.54	AUG 31	3655.82	SEP 30	3678.10
JUL 31	3484.35	AUG 31	3575.94	SEP 30	3651.73	OCT 31	3676.13
AUG 31	3490.28	SEP 30	3573.32	OCT 31	3650.71	NOV 30	3673.50
SEP 30	3491.69	OCT 31	3574.90	NOV 30	3649.46	DEC 31	3672.68
OCT 31	3491.70	NOV 30	3574.21	DEC 31	3648.27	JAN 31, 1980	3673.03
NOV 30	3491.42	DEC 31	3572.11	JAN 31, 1975	3645.78	FEB 28	3674.26
DEC 31	3491.94	JAN 31, 1970	3569.37	FEB 28	3645.34	MAR 31	3675.54
JAN 31, 1965	3491.41	FEB 28	3570.13	MAR 31	3646.10	APR 30	3677.64
FEB 28	3491.91	MAR 31	3571.27	APR 30	3647.81	MAY 31	3691.72
MAR 31	3491.88	APR 30	3566.65	MAY 31	3655.60	JUN 30	3700.50
APR 30	3490.91	MAY 31	3582.13	JUN 30	3668.90	JUL 31	3696.40
MAY 31	3491.82	JUN 30	3599.13	JUL 31	3674.81	AUG 31	3690.48
JUN 30	3510.85	JUL 31	3600.88	AUG 31	3671.89	SEP 30	3687.78
JUL 31	3530.91	AUG 31	3597.90	SEP 30	3668.06	OCT 31	3685.47
AUG 31	3531.34	SEP 30	3598.87	OCT 31	3666.57	NOV 30	3682.81
SEP 30	3530.12	OCT 31	3599.84	NOV 30	3667.15	DEC 31	3681.28
OCT 31	3531.57	NOV 30	3600.89	DEC 31	3667.88	JAN 31, 1981	3679.57
NOV 30	3531.93	DEC 31	3599.78	JAN 31, 1976	3666.77	FEB 28	3678.09
DEC 31	3534.44	JAN 31, 1971	3600.79	FEB 28	3665.43	MAR 31	3677.75
JAN 31, 1966	3536.00	FEB 28	3602.66	MAR 31	3664.70	APR 30	3677.25
FEB 28	3534.11	MAR 31	3602.86	APR 30	3664.17	MAY 31	3677.76
MAR 31	3536.06	APR 30	3603.62	MAY 31	3667.76	JUN 30	3680.61
APR 30	3538.76	MAY 31	3608.73	JUN 30	3672.16	JUL 31	3677.79
MAY 31	3544.54	JUN 30	3620.79	JUL 31	3670.39	AUG 31	3673.44
JUN 30	3545.12	JUL 31	3620.80	AUG 31	3667.44	SEP 30	3671.96
JUL 31	3541.05	AUG 31	3617.31	SEP 30	3664.00	OCT 31	3671.94
AUG 31	3535.43	SEP 30	3614.25	OCT 31	3661.24	NOV 30	3670.68
SEP 30	3531.86	OCT 31	3614.15	NOV 30	3657.89	DEC 31	3667.47
OCT 31	3527.29	NOV 30	3612.42	DEC 31	3655.31	JAN 31, 1982	3663.75
NOV 30	3523.92	DEC 31	3609.56	JAN 31, 1977	3651.78	FEB 23	3662.75
DEC 31	3522.39	JAN 31, 1972	3607.87	FEB 28	3651.38	MAR 31	3663.96
JAN 31, 1967	3517.39	FEB 28	3609.51	MAR 31	3651.20	APR 30	3665.59
FEB 28	3515.15	MAR 31	3612.74	APR 30	3652.63	MAY 31	3674.59
MAR 31	3515.22	APR 30	3610.58	MAY 31	3654.27	JUN 30	3684.92
APR 30	3514.58	MAY 31	3611.92	JUN 30	3653.65	JUL 31	3687.35
MAY 31	3509.69	JUN 30	3619.57	JUL 31	3649.36	AUG 31	3686.64
JUN 30	3529.15	JUL 31	3615.43	AUG 31	3642.48	SEP 30	3687.27
JUL 31	3532.53	AUG 31	3609.12	SEP 30	3636.70	OCT 31	3687.65
AUG 31	3530.48	SEP 30	3603.40	OCT 31	3635.65	NOV 30	3686.26
SEP 30	3528.45	OCT 31	3609.09	NOV 30	3634.62	DEC 31	3684.74
OCT 31	3528.40	NOV 30	3609.51	DEC 31	3630.05		
NOV 30	3528.40	DEC 31	3606.20	JAN 31, 1978	3625.02		
DEC 31	3527.30	JAN 31, 1973	3601.04	FEB 28	3622.71		
JAN 31, 1968	3525.23	FEB 28	3600.68	MAR 31	3622.69		
FEB 28	3526.09	MAR 31	3598.12	APR 30	3626.85		
MAR 31	3520.48	APR 30	3590.63	MAY 31	3635.62		

Table 16.--Chemical analyses of trace elements
[Abbreviations used in column headings are as follows:

Station number or name: See "Numbering system for hydrogeologic-data sites", p. 5, and figure 2.
Site: GW, ground water; LK, lake; SP, spring; SW, stream.
Geologic unit: 220NVJO, Navajo Sandstone; 220GLNC, Glen Canyon Group; 221ENRD, Entrada Sandstone.

STATION NUMBER OR NAME	SITE	GEO-LOGIC UNIT	DATE OF SAMPLE	ARSENIC TOTAL (µg/L AS AS)	ARSENIC DIS-SOLVED (µg/L AS AS)	BARIUM DIS-SOLVED (µg/L AS BA)	BORON DIS-SOLVED (µg/L AS B)
(C-41- 3) 4BCA- 1	GW	220NVJO	81-06-12	--	0	500	--
(C-43- 1) 3BAC- 1	GW	220NVJO	81-02-25	--	1	50	--
(D-33- 4)35BBD- 1	GW	220NVJO	81-04-23	--	6	300	--
36ABB- 1	GW	220NVJO	81-09-01	--	22	270	--
(D-33- 5)31ADC- 1	GW	220NVJO	81-09-01	--	3	57	--
(D-34- 4) 1CAD- 1	GW	220NVJO	81-09-01	--	12	78	--
(D-35- 3) 8ABA- 1	GW	221ENRD	81-09-03	--	0	37	--
(D-43- 1) 2BDD- 1	GW	220NVJO	79-09-26	--	--	30	--
(D-43- 2)13DCD- 1	GW	221ENRD	81-06-18	--	11	100	--
(A-39- 4) 6CBB- 1	GW	220GLNC	76-08-05	--	--	--	40
(A-40- 5)12DDB- 1	GW	220NVJO	76-08-05	--	--	--	30
33CBC- 1	GW	220NVJO	76-08-05	--	--	--	40
(A-41- 4)28ADA- 1	GW	220GLNC	76-08-06	--	--	--	30
(A-41- 8) 4DDA- 1	GW	220NVJO	74-03-03[1]	<10	--	--	--
			77-04-05[1]	1	1	--	--
			77-10-18	--	13	--	130
			81-08-31	--	13	36	--
14BCA- 1	GW	220NVJO	77-10-19	--	2	--	110
			81-04-02	--	4	40	--
14BCB- 1	GW	220NVJO	58-03-10[2]	--	--	--	--
23DAC- 1	GW	220NVJO	81-08-29	--	0	44	--
23DCD- 1	GW	220NVJO	58-03-10[2]	--	--	--	--
			81-08-28	--	33	530	--
(A-42- 8)32CDD- 1	GW	220NVJO	73-03-23[1]	<10	--	--	--
			73-08-15[1]	10	--	--	--
			77-09-09[1]	<5	--	--	--
			77-09-09[1]	--	<5	--	--
			81-06-11	--	1	100	--
35DAB- 2	GW	220NVJO	72-04-27[2]	50	--	--	--
			77-04-05[2]	90	--	--	--
			77-04-05[2]	60	60	--	--
			77-09-13[2]	59	--	--	--
			77-10-18	--	40	--	220
			77-12-05[1]	48	--	--	--
			81-04-22	--	40	30	--
35DCD- 1	GW	220NVJO	76-11-00[2]	40	--	--	--
			77-03-01[2]	70	70	--	--
			77-04-00[1]	30	30	--	--
			77-04-05[2]	40	40	--	--
			77-09-13[2]	40	--	--	--
			77-09-28[2]	36	36	--	--
			77-09-28[1]	37	37	--	--
			77-10-18	--	30	--	160
			77-12-05[1]	50	--	--	--
36CBC- 1	GW	220NVJO	58-08-20[3]	--	--	--	--
36CCC- 2	GW	220NVJO	68-05-22[1]	--	--	--	390
			72-04-27[2]	50	--	--	--
			76-11-00[2]	90	--	--	--
			77-04-05[2]	60	--	--	--
			77-04-05[2]	50	50	--	--
			77-09-13[2]	50	--	--	--
			77-10-18	--	30	--	110
			77-12-05[1]	52	--	--	--
(C-40- 1)23BBA-S1	SP	220NVJO	79-09-25	--	--	140	--
ESCALANTE R AB MAMIE CR AT (D-35- 4) 7BDD	SW	--	81-10-21	--	3	71	--
ESCALANTE R AB BOULDER CR AT (D-35- 5)22BBB	SW	--	81-10-21	--	4	81	--
BOULDER CREEK AT MOUTH AT (D-35- 5)22BBB	SW	--	81-10-21	--	4	63	--
ESCALANTE R AB TRIB AT (D-37- 7) 6DCD	SW	--	81-10-22	--	4	85	--
PARIA R AB SHEEP CR AT (C-39- 2)17BDB	SW	--	81-10-23	--	1	46	--
PARIA R AB DEER CR AT (C-40- 2) 4AAB	SW	--	81-10-23	--	1	53	--
PARIA R 3 MI SO HY 89 AT (C-43- 1)15AAC	SW	--	81-10-23	--	1	59	--
PARIA R AB KAIBAB GULCH AT (C-44- 1)12CCA	SW	--	81-10-23	--	2	60	--
LAKE POWELL AT (A-42- 8)36CAB	LK	--	77-10-18[1]	--	2	--	100
COLORADO R AT LEES FERRY, AZ	SW	--	77-02-03	3	3	--	90
			77-05-03	1	1	--	90
			77-08-09	2	1	--	100
			77-11-04	2	2	200	90

[1] From files of U.S. Geological Survey, source of data unknown.
[2] Analysis by Arizona State Department of Health.
[3] Analysis by Arizona Testing Laboratories, Phoenix, Arizona.

in ground and surface water at selected sites
µg/L, micrograms per liter; pci/L, picocuries per liter.]

CADMIUM TOTAL RECOV-ERABLE (µg/L AS CD)	CHRO-MIUM TOTAL RECOV-ERABLE (µg/L AS CR)	COBALT DIS-SOLVED (µg/L AS CO)	COPPER TOTAL RECOV-ERABLE (µg/L AS CU)	MERCURY TOTAL RECOV-ERABLE (µg/L AS HG)	IRON TOTAL RECOV-ERABLE (µg/L AS FE)	IRON DIS-SOLVED (µg/L AS FE)	LEAD TOTAL RECOV-ERABLE (µg/L AS PB)	SELE-NIUM DIS-SOLVED (µg/L AS SE)	SILVER TOTAL RECOV-ERABLE (µg/L AS AG)	STRON-TIUM DIS-SOLVED (µg/L AS SR)	ZINC TOTAL RECOV-ERABLE (µg/L AS ZN)	POTAS-SIUM 40 DIS-SOLVED (pci/L AS K40)
--	--	--	--	--	--	30	--	0	--	230	--	1.3
--	--	--	--	--	--	1500	--	0	--	3600	--	5.3
--	--	--	--	--	--	10	--	0	--	220	--	2.1
--	--	--	--	--	--	<10	--	1	--	760	--	--
--	--	--	--	--	--	19	--	0	--	240	--	--
--	--	--	--	--	--	<10	--	0	--	460	--	--
--	--	--	--	--	--	<10	--	1	--	2000	--	--
--	--	<3	--	--	--	39	--	--	--	1600	--	--
--	--	--	--	--	--	<10	--	0	--	70	--	1.0
--	--	--	--	--	--	<10	--	--	--	--	--	--
--	--	--	--	--	--	<10	--	--	--	--	--	--
--	--	--	--	--	--	<10	--	--	--	--	--	--
--	--	--	--	--	--	<10	--	--	--	--	--	--
<20	<20	--	<50	<5.0	--	--	<50	--	<20	--	<70	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	60	--	3	--	--	--	--
--	--	--	--	--	--	37	--	3	--	1300	--	--
--	--	--	--	--	--	40	--	2	--	--	--	--
--	--	--	--	--	--	30	--	2	--	1100	--	8.2
--	--	--	--	--	--	0	--	--	--	--	--	--
--	--	--	--	--	--	12	--	0	--	49	--	--
--	--	--	--	--	--	0	--	--	--	--	--	--
--	--	--	--	--	--	10	--	1	--	300	--	--
<20	<20	--	<50	<5.0	<50	--	<30	--	<20	--	50	--
<20	<20	--	<50	<5.0	<50	--	<50	--	<20	--	70	--
<5	<20	--	<50	<5.0	--	--	<20	--	<2	--	<65	--
--	--	--	--	--	110	--	--	<5	--	--	--	--
--	--	--	--	--	--	60	--	1	--	1500	--	5.4
<10	<10	--	<50	<5.0	<50	--	<50	--	<10	--	<10	--
<5	<20	--	1120	<5.0	740	--	<20	--	<20	--	<50	--
--	--	--	--	--	--	--	--	--	--	--	--	--
<5	<20	--	60	<5.0	13	--	<20	--	<20	--	50	--
--	--	--	--	--	--	170	--	2	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	230	--	3	--	1500	--	13
<20	<20	--	<50	<.5	100	--	<50	--	<20	--	<60	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
<5	<20	--	<50	<5.0	<50	--	<20	--	<20	--	<50	--
--	--	--	--	--	--	--	--	10	--	--	--	--
--	--	--	--	--	--	--	--	10	--	--	--	--
--	--	--	--	--	--	70	--	21	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	--	--	--	--	0	--	--	--	--	--	--
--	--	--	--	--	150	30	--	--	--	--	--	--
<10	<10	--	<50	<.5	<50	--	<50	--	<10	--	<50	--
<20	<20	--	<50	<.5	2040	--	<50	--	<20	--	100	--
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--	--	--	--	--	--	--	--	--	--	--	--	--
<5	<20	--	<50	<5.0	150	--	<20	--	<20	--	<50	--
--	--	--	--	--	--	180	--	3	--	--	--	--
--	--	--	--	--	--	--	--	--	--	--	--	--
--	--	<3	--	--	--	<10	--	--	--	1500	--	--
--	--	--	--	--	--	<10	--	<1	--	550	--	--
--	--	--	--	--	--	<10	--	<1	--	630	--	--
--	--	--	--	--	--	23	--	<1	--	200	--	--
--	--	--	--	--	--	<10	--	<1	--	440	--	--
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<20	4	--	<20	<.1	50	<10	<200	4	<20	--	<20	--

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UNITED STATES DEPARTMENT OF THE INTERIOR
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EXPLANATION

D,Q,W ● INVENTORIED WELL (table 12)

Jca ●~ INVENTORIED SPRING (tables 2 and 9)

□ Je LOCATION OF SHALLOW CORE OR OUTCROP USED I
LABORATORY ANALYSES (table 3)

Letters next to symbol indicate:

Basic data: D, driller's log (table 11);
Q, water-quality analysis (tables 14 and 16);
W, water-level record (table 13).

Geologic source: Je, Entrada Sandstone; Jca, Carmel Formation; ₮wi, Wingate Sandstone; no symbol, Navajo Sandstone.

09339500 ▲ STREAMFLOW-GAGING STATION AND NUMBER (tab

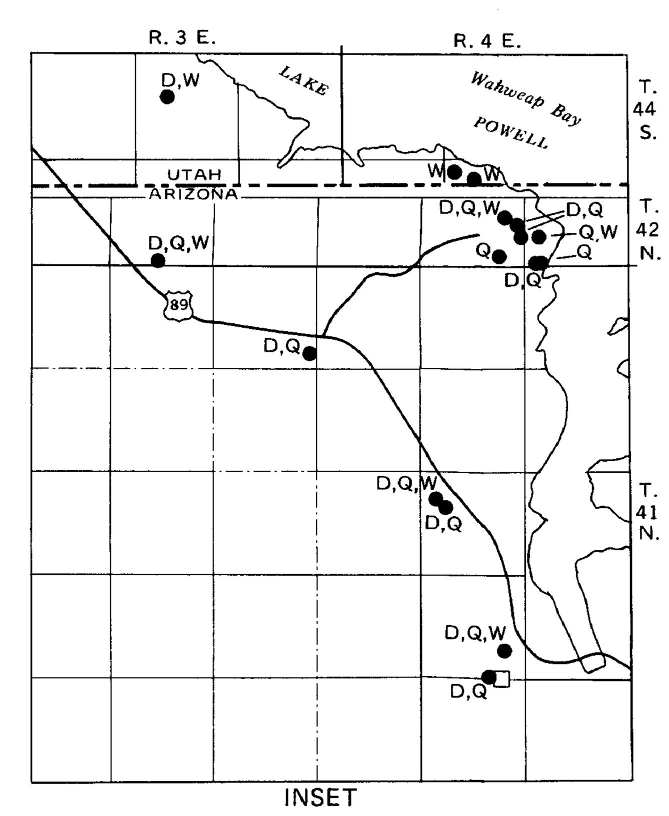
Q△ SITE OF MISCELLANEOUS STREAMFLOW MEASUREMENT (table 6)

Q, water-quality analysis (tables 14, and 16)

—10— LINE OF EQUAL NORMAL ANNUAL PRECIPITATION
Contour interval 2, 4, and 5 inches

•—3—• LINE OF EQUAL NORMAL MAY-SEPTEMBER PRECIPITATION—Contour interval 1 and 2 inches

—••— BOUNDARY OF STUDY AREA



INSET

MAP SHOWING SELECTED HYDROGEOLOGIC INFORMATION IN THE KAIPAROWITS PLATEAU AREA, UTAH AND ARIZONA

Base from U. S. Geological Survey 1:250,000 quadrangles: Salina, Utah, 1956, revised 1970; Cedar City, Utah, 1953, revised 1971; Escalante, Utah, Arizona, 1956, revised 1970; Grand Canyon, Arizona, 1953, revised 1970; Marble Canyon, Arizona, 1956, revised 1970.

Normal annual and May-September precipitati from U. S. Weather Bureau (1931-60)